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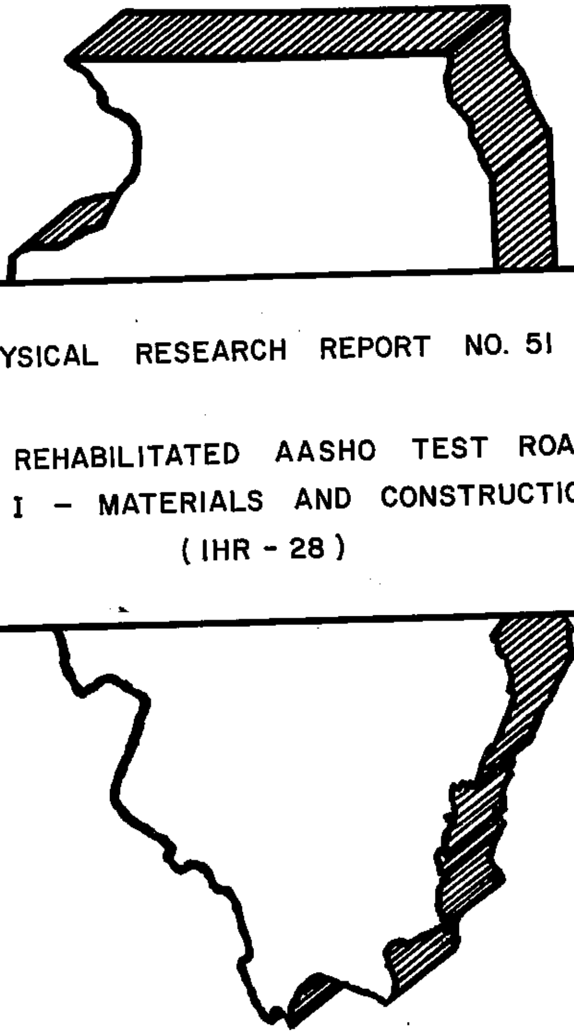

PHYSICAL RESEARCH REPORT NO. 51

THE REHABILITATED AASHO TEST ROAD
PART I - MATERIALS AND CONSTRUCTION
(IHR - 28)

MATERIALS & PHYSICAL RESEARCH

ILLINOIS DEPARTMENT OF TRANSPORTATION

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State of Illinois
DEPARTMENT OF TRANSPORTATION
Bureau of Materials and Physical Research

THE REHABILITATED AASHO TEST ROAD
PART I - MATERIALS AND CONSTRUCTION

By

R. J. Little, L. J. McKenzie, and P. G. Dierstein

Interim Report
IHR-28

AASHO Road Test

A Research Project Conducted by
Illinois Department of Transportation
in cooperation with
U. S. Department of Transportation
Federal Highway Administration

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16. Abstract

The Working Committee for the AASHO Road Test project recommended extending the study of the AASHO Road Test under mixed traffic at the site near Ottawa, Illinois. At the close of controlled testing, new rigid and flexible test sections were added as links between the test tangents of the four major loops and as replacement test sections for those which either had failed or were inadequate by interstate standards. New subbase materials introduced under rigid pavement were crushed stone, gravel, bituminous-aggregate mixture and cement-aggregate mixture, but the only new subbase material used under the flexible pavement was gravel. Except for portland cement concrete, base materials such as salvaged crushed stone-special, crushed stone, bituminous- and cement-aggregate mixtures were similar to those used in the original AASHO Test Road. As a side study, the bituminous surface was altered in several test sections either by adding asbestos to or by substituting hydrated lime and kaolin clay for limestone dust mineral filler. The new experimental highway, which was opened to traffic in November 1962 as a part of Interstate 80, has 85 rigid and 43 flexible test sections.

17. Key Words AASHO Road Test, rigid pavement, flexible pavement, materials, construction, embankment, subbases, bases, surfacing, resurfacing, mineral fillers, aggregate gradation, compaction, density, and Marshall Mix Design Method	18. Distribution Statement

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PART I - MATERIALS AND CONSTRUCTION

INTRODUCTION

The American Association of State Highway Officials (AASHO) Road Test, conducted at Ottawa, Illinois, during 1956-1960, was conceived as a study of the performance of pavements and bridges of known structural designs while carrying moving loads of known magnitude, type, and frequency. Recognizing the need for further study under mixed traffic, the Working Committee, which was a subcommittee of the AASHO Committee on Highway Transport, recommended that limited research studies be continued at the site following the close of the controlled testing. Their recommendation, included in a final report of May 1955 entitled "Statement of Fundamental Principles, Project Elements, and Specific Directions," stated that the objectives of the continued studies were to (1) provide a continuing record of the behavior of representative test sections under varying frequency of heavy axle loadings, (2) measure the relative highway costs necessary to accommodate the normal traffic on each of the test section variables, and (3) reconcile the effects of normal mixed-traffic loads with those of the controlled loadings of the Road Test.

At the close of controlled testing, the facility was rehabilitated as an experimental four-lane divided highway (Figure 1) and was opened to vehicular traffic as part of Interstate 80 in November 1962. This report, which is the first of a three-part final report, gives a brief resume of the AASHO Road Test, describes the reconstructed test facility, and discusses the materials and the construction procedures that were used to rehabilitate the test facility. The second part of the final report will describe the behavior of rigid pavement, while the third part will describe the behavior of flexible pavement.

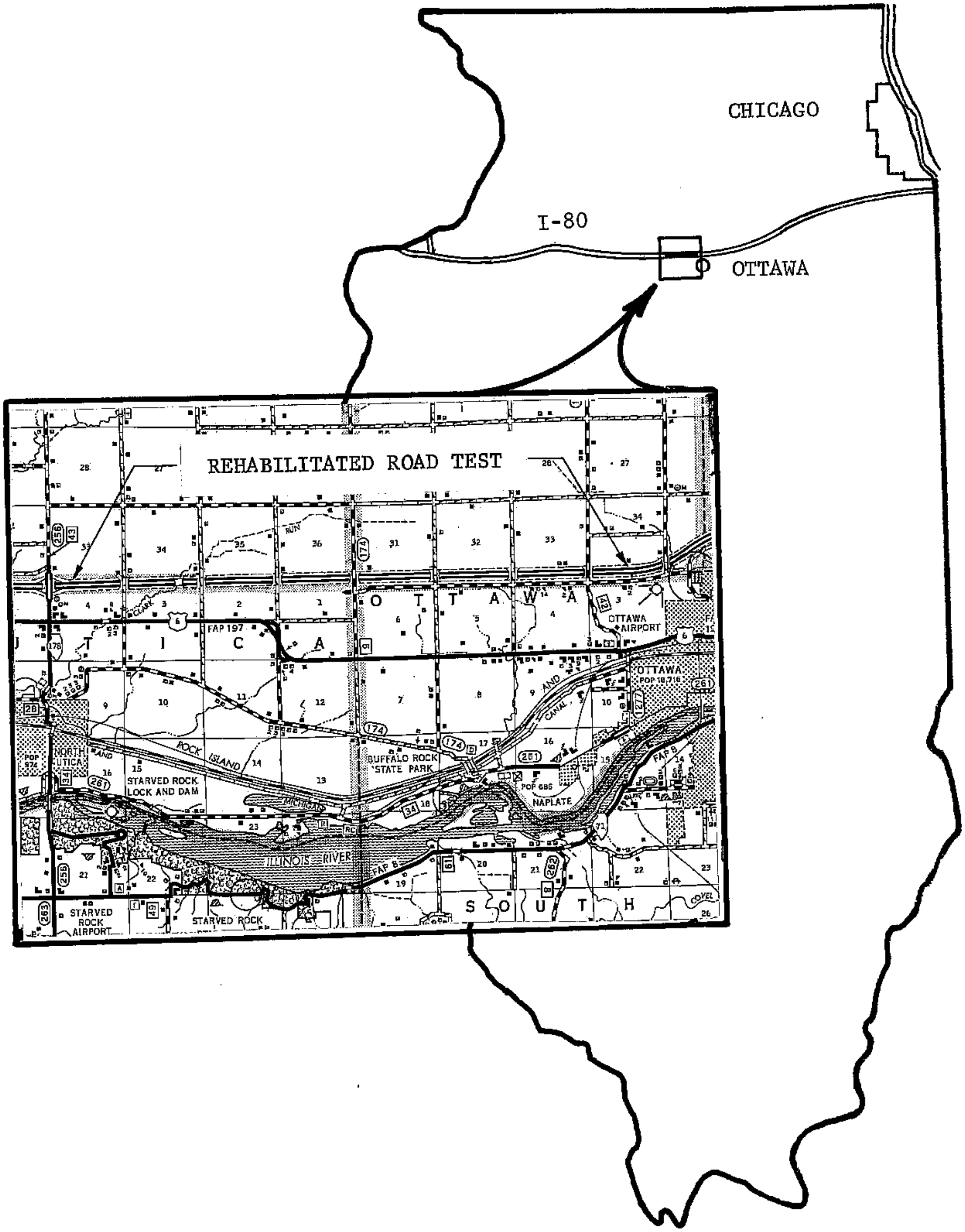

Figure 1. Map showing location of Rehabilitated AASHO Test Road.

The work that has been accomplished since correlative research began in 1962 is described in eight reports. In 1965, the Road Test equations for design of pavements were modified to apply to bituminous pavements in Illinois by Chastain and Schwartz 1/ and to portland cement concrete pavements by Chastain and others 2/. Subsequently, the procedures outlined were adopted as standard design policy for bituminous and portland cement concrete pavements in Illinois. Later, in 1969, Schwartz and Warning 3/ reported on a procedure being developed for determining the thickness of asphaltic concrete overlays and, in 1970, design coefficients for lime-soil mixtures as base and subbase were added to the flexible design policy 4/. More recently, in July 1971, Kubiak and Jacobsen 5/ described an experiment in weighing vehicles in motion and, in August 1971, Little 6/ reported on a field experiment with mineral fillers for asphalt paving mixtures. In November 1971, Elliott 16/ reported on a thickness design procedure for resurfacing concrete pavement and, in April 1972, Chastain and Elliott 17/ reported the results of a traffic evaluation of Illinois Pavement Design. Another report that describes the behavior of contraction joints in rigid pavements is in preparation.

HISTORY

In November 1954, the American Association of State Highway Officials approved undertaking the AASHO Road Test project near Ottawa, Illinois, and Illinois agreed to accept the responsibility as host State. The site that was approved was located in LaSalle County about 80 miles southwest of Chicago between Ottawa and Utica (Figure 1). As host State, Illinois agreed to finance construction of the facility through Federal aid to the extent of the cost of a four-lane divided highway through the test area. In addition, the Illinois Division of Highways purchased right of way, prepared plans and specifications, and supervised construction of the test facility. Financing of the remainder of the project was shared among the 48 states, Hawaii, District of Columbia, Territory of Puerto Rico, Bureau of Public Roads, American Petroleum Institute, American Institute of Steel Construction, Department of Defense, and other agencies.

Six special reports 7-12/, published by the Highway Research Board (HRB), describe the history of the AASHO Road Test, discuss materials and construction procedures used to build the test loops, report test vehicle operations and test section maintenance, give an account of bridge research, present rigid and flexible pavement research findings, and discuss special studies conducted in conjunction with the main factorial experiment.

Seven technical papers were presented by the research staff at the 40th Annual Meeting of the Highway Research Board in January 1961 13/.

In May 1962, following completion of the study, the Highway Research Board sponsored a conference at St. Louis where the Road Test staff officially presented the study findings to highway engineers, administrators, university representatives, and representatives of associated industries. The proceedings of this conference were published in Special Report No. 73 14/ prepared by the Highway Research Board.

Two papers, one presented by Chastain at the St. Louis Conference and the other given by Chastain and Burke 15/ at the International Conference on Structural Design of Bituminous Pavement at Ann Arbor, Michigan in August 1962, discuss the relation of post Road Test research to the AASHO Road Test.

Post Road Test research was a necessary sequel to the major study that furnished two basic pavement performance equations--one applying to rigid pavements and the other applying to flexible pavements. Each equation described the performance of various pavement designs when subjected to 1,114,000 axle loads of a given weight and type. As developed, the equations are limited in pavement design work because they represent pavement performance restricted to soils, climate, and construction conditions that are unique to the Road Test site. Moreover, the equations represent controlled loading not directly applicable to mixed loading that varies in type and in weight, and they were based on a relatively small number of axle-load repetitions in contrast to numerous mixed-axle loads that pavements carry during a normal service lifetime. It was evident that the pavement performance-axle load relationships expressed by the equations needed further study and modification before they could be applied to the design of regular highways in environments that differ from those at the Road Test site.

Statistical principles were followed in the design of the AASHO Road Test experiment. Because both space and funds were limited, only parameters that were of prime importance to the major objectives of the research and that could not be conveniently studied by other means were selected for investigation. Some of the parameters studied were limited to the extent that a statistical analysis was impossible. Other parameters, on which information was needed in regular highway work, had to be excluded entirely from the main factorial designs. Adding further to the rigor of the research, axle loadings applied to the experimental pavements of the Road Test were rigidly controlled, both as to weight and type. In contrast, the traffic that normally uses the highway system includes many types of vehicles and a wide range of axle loadings. Because of the limitations imposed by the rigor of the experimentation, successful application of the pavement behavior-axle load relationships derived from the research depended on extending the findings to new and untested structural materials and to new pavement designs, and on establishing a relation between controlled Road Test loadings and mixed loadings characteristic of normal highway traffic.

Rehabilitation of the AASHO Test Road has provided a unique opportunity to study the effects of normal mixed traffic on many of the Road Test designs, to make comparisons with new structural materials and new designs in the Road Test environment, to further verify the pavement behavior-axle load relationships expressed by the Road Test equations, and to facilitate extending them to new pavements under soil and climate conditions different from those of the Road Test site.

OBJECTIVES

The research that has continued since 1962 has conformed, generally, to the pavement performance studies carried on during the AASHO Road Test. The performance of original test sections side by side with new replicate sections and of newly constructed test sections that incorporate new structural materials is being studied under normal mixed traffic. In 1965, the work plan was revised to divide the research into two parts, one that entailed continued study of original and new replicate Road Test sections under normal mixed traffic and the other that involved development of formulas and procedures for applying the original AASHO Road Test results in structural design and evaluation of pavement in Illinois. In 1970, the work plan was revised again to emphasize short-term behavior rather than long-term performance objectives. Now the objectives of the study are to

(1) evaluate the behavior of the surviving original portland cement concrete (PCC) test sections and new replicate test sections under regular mixed traffic.

(2) determine the effect of subbase type on PCC pavement behavior.

(3) determine the effect of joint spacing on the behavior of transverse contraction joints and pavement panels.

(4) evaluate the behavior of the resurfaced original flexible pavement test sections.

(5) determine the effect of base type on flexible pavement behavior.

(6) determine the effect of different mineral fillers on the physical characteristics, strength, and subsequent behavior of asphalt concrete surface and binder courses.

(7) develop procedures for applying the findings of the AASHO Road Test research in the structural design of highway pavements in Illinois.

Phase 1 of the research now includes Objectives 1 through 6, whereas Phase 2 is concerned only with Objective 7.

EXPERIMENTAL LAYOUT

The original test tangents of the four major loops were constructed along the alignment of Interstate 80 (Figure 2). At the close of the Road Test, the turnarounds were removed, and a new four-lane divided highway was constructed through the test area by connecting the test tangents with new pavement. Experimental pavements within the test tangents that were damaged by test traffic and Road Test pavements that did not meet Interstate highway standards were removed and were replaced with new pavement, while experimental pavements that survived test traffic and that met Interstate highway standards were retained for further testing.

New experimental pavements were constructed either as links between the test tangents or as replacements for test sections that had been removed. Some of these new test sections, constructed from salvaged materials, represented original Road Test designs while others represented new designs that incorporated new structural materials that differ from those used in the AASHO Road Test. When traffic tests

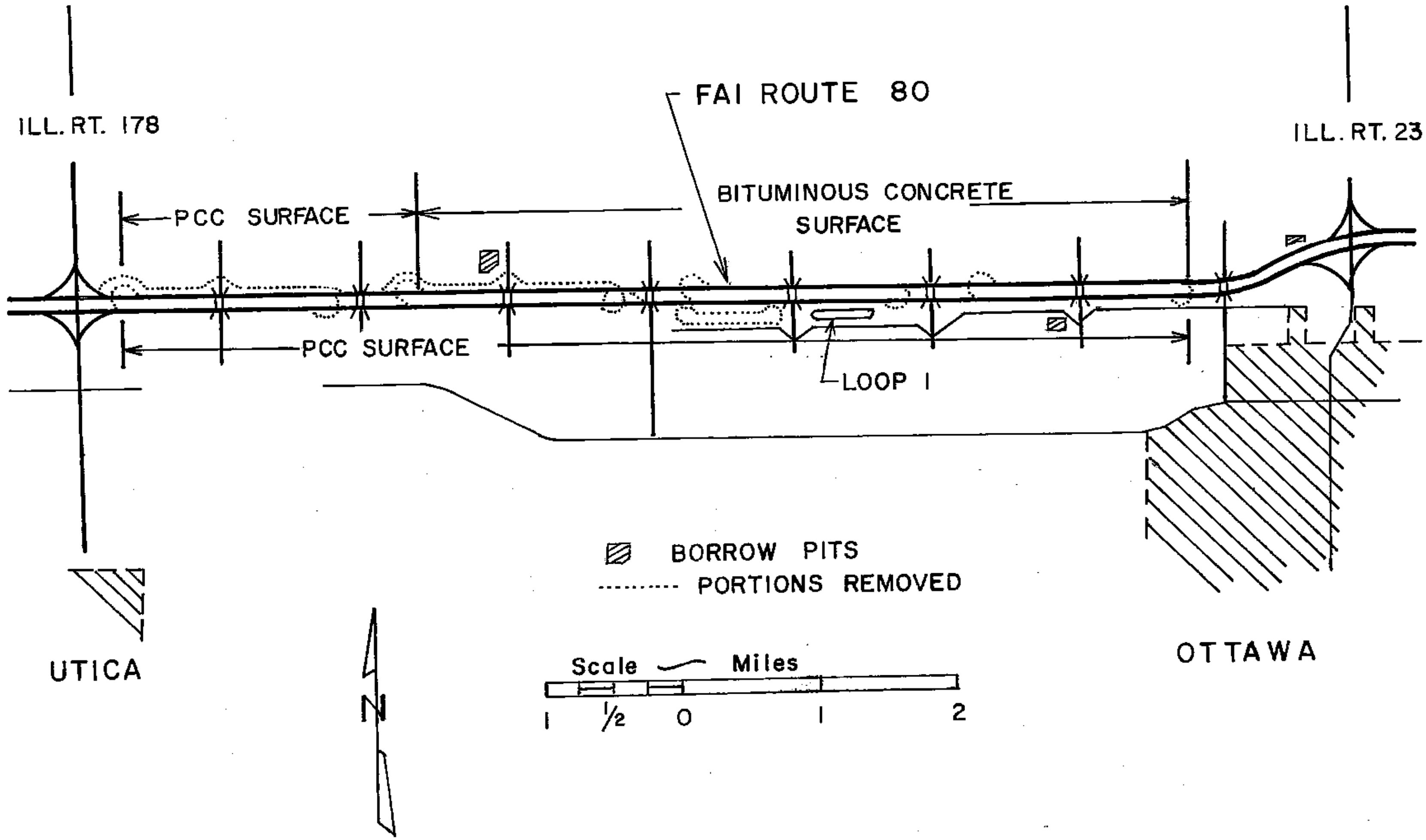

Figure 2. Layout of the Rehabilitated AASHO Test Road.

were completed on the original facility, rutting and cracking in most flexible surfaces had progressed to a point where general resurfacing was required to adequately restore the pavements for Interstate System service, so the new experiment also included a test of bituminous concrete overlays.

Generally, experimental pavements in the rehabilitated test road comprise six test section categories, those which are (1) new and original rigid pavements, (2) resurfaced flexible pavements, (3) new flexible pavements, (4) resurfaced flexible pavements with wedge base, (5) rigid pavements Loop 1, and (6) flexible pavements Loop 1. Moreover, each category forms a table that has been further divided into groups which have the same type and thickness of surface, base, and subbase, and the three digit numbers listed in each table identify test sections assigned to that group.

The identity of all rigid pavement test sections that were retained from the original Road Test and that were constructed new during rehabilitation are in Table 1.

Flexible pavement test sections are recorded in Tables 2, 3, and 4. All test sections that survived the original testing with at least a PSI of 1.5 were resurfaced and are identified in Table 2, except for wedge base course test sections which are listed in Table 4.

The new flexible test sections are recorded in Table 3. They include duplicates of original Road Test designs and new designs which use gravel, crushed stone, bituminous-aggregate mixture (BAM), cement-aggregate mixture (CAM) and portland cement concrete (PCC) as base materials, and crushed stone and gravel as subbase materials.

The rigid and flexible test sections in Loop 1, which is located to the south of Interstate 80 and which carried no traffic are shown in Tables 5 and 6 respectively.

TABLE 1

TEST SECTION NUMBERS FOR RIGID PAVEMENT DESIGNS

Subbase Type	Subbase Thickness (in.)	PCC Pavement Thickness (in.) Reinforced 8	Reinforced 9.5	Reinforced 10	Reinforced 11	Reinforced 12.5	Non-Reinforced 8	Non-Reinforced 9.5	Non-Reinforced 11	Non-Reinforced 12.5
BAM	4	070,082	072,080	058						
CAM	4	084,094	086,096	060						
SGM	3	692	382,554 646		392,516	360	672	352,512 542,676	364,378 530	396
	4			386						
	5.5			506,550						
	6	670	404,504 544,666	[illegible]	338,346 546	356	658	368,390 528,702	388,398 498	350
	7			348,508						
	8.5			340						
	9	696	500,668		344,496	358	652	376,690	366,510	380
New SGM 1/	6	092	078							
Gravel	6	068,074	066,076	A2D,A4D 342,384 D2C,490 538,548 520,D2A C2B,D4C						
Crushed Stone	6	064,088	062,090							
No Subbase	0							552		

1/ New sand-gravel material that was obtained from an unused stockpile in a pit at the west end of the construction site.

TABLE 2

TEST SECTION NUMBERS FOR RESURFACED FLEXIBLE PAVEMENT DESIGNS

Surface Thickness Total[1/] (in.)	Surface Thickness Original (in.)	Base Thickness (in.)	SGM Subbase Thickness 8 in.	SGM Subbase Thickness 12 in.	SGM Subbase Thickness 16 in.
9	4	6	578	--	--
9.5	4	6	--	626	--
10	5	6	592	--	--
	4	9	--	478	310
10.5	5	9	--	--	266
11	5,6 [2/]	3	--	480	256
	5	6	--	582	--
	5,6	9	--	428	334
11.5	6	6	--	258	--
	6	9	272	--	--
12.0	5,6	6	470	--	302
	6,6	9	264	312	--

1/ The total surface thickness comprises the original surface and the new overlay thickness.

2/ Double numbers indicate the original thickness of each test section in the category in consecutive order.

TABLE 3

TEST SECTION NUMBERS FOR NEW FLEXIBLE PAVEMENT DESIGNS

Base Course		Subbase Course		Thickness of Bituminous Surface (in.)			
Type 1/	Thickness (in.)	Type 1/	Thickness (in.)	3.0	4.0	4.5	5.0
BAM	8	Gravel	4	--	-	026,020	-
	10	Gravel	4	-	-	042,030,022	-
	12	Gravel	4	-	-	024	-
CAM	10	Gravel	4	-	-	008,006	-
	12	Gravel	4	-	-	040,028,010,004	-
	14	Gravel	4	-	-	002	-
PCC	8	Mixed	Variable	048,034,012	-		-
	9.5	Mixed	Variable	046,036,014			
BC (Salvaged)	6	SGM	12	-	018	-	016
Crushed Stone	8.5	Gravel	23	-	-	038	-

1/ BAM - Bituminous Stabilized Base
PCC - Portland Cement Concrete Base
SGM - Sand-Gravel Material
CAM - Cement Stabilized Base
BC - Crushed Stone Base, Special

TABLE 4

TEST SECTION NUMBERS FOR RESURFACED FLEXIBLE PAVEMENTS WITH WEDGE BASES

Surface Thickness		Bituminous Stabilized Base Thickness (in.)	SGM Subbase Thickness (in.)	Test Section No.
Total (in.)	Original (in.)			
8.5	3	5.5 - 16	4	460
9.0	3	5.0 - 16	4	464
9.5	4	7.0 - 18	4	284,286

TABLE 5

TEST SECTION NUMBERS FOR LOOP 1 RIGID PAVEMENTS

Surface Thickness (in.)	Reinforcement 1/	Subbase Thickness (in.) 2/ 0	6
2.5	R	895,897	899,931
	NR	935	933
5.0	R	905	927
	NR	889,893 903,923	891,901 925,929
9.5	R	907,921	887,915
	NR	919	917
12.5	R	883	911
	NR	881,885	909,913

1/ R = Reinforced; NR = Non-reinforced

2/ Sand-Gravel Material

TABLE 6

TEST SECTION NUMBERS FOR LOOP 1 FLEXIBLE PAVEMENTS

Surface Thickness (in.)	Base 1/ Thickness (in.)	Subbase 2/ Thickness (in.) 0	8	16
1	0	857	867	833,841
	6	827	847	839
3	0	859,861 863	829,831 853,869	817 837
	6	825,851 855	819,845 875	821,835 843
5	0	823	865	877
	6	871	849	873,879

1/ Crushed Stone, Special

2/ Sand-Gravel Material

The layout of test sections in mainline pavements and in Loop 1 is shown in Figures A-1 and A-2, respectively. These figures show plan and elevation views of each test section in the rehabilitated test road. In the plan views, the blank spaces represent pavement sections that are transitional from one experimental design to another and that are unsatisfactory for testing purposes, while numbered spaces represent test sections in the rehabilitated test road.

Each test section has a three-digit number which consists of either numerals or numerals and letters. A numeral from 1 to 9 used as the first digit in the code number identifies original rigid and flexible test sections, newly constructed sections that replaced old sections in the original test tangents, and test sections in Loop 1. A zero used as the first digit in the code number identifies new test sections that are replicates of original Road Test designs, and new sections that utilized new materials not used in the Road Test. When a letter replaces the first and third digits in a code number, it identifies new rigid test sections in either the eastbound or westbound pavement that connect original test tangents.

The restored Road Test facility now has 85 rigid and 43 flexible test sections that extend full pavement width in the mainline pavement. Beside these are the test sections in Loop 1. Test sections that remain from the original rigid test are either 120 or 240 feet long. New test sections range up to 2,900 feet in length. As were the original test sections, the new sections of pavement are placed on a special 3-foot embankment of A-6 soil salvaged from the loop turn-arounds. Loop 2 was dismantled, and the materials were salvaged and used as needed in the new mainline pavement sections and in the approaches to new overhead structures.

All the rigid pavement test sections except test section D2A, which connects Loop 3 and Loop 6 in the westbound roadway, are located in the eastbound roadway, and vary in thickness of surfacing and subbase. In the rehabilitation, bituminous aggregate mixture (BAM), cement-aggregate mixture (CAM), gravel, and crushed stone materials were added as subbase variables. In addition to surface thickness, the rigid pavement experiment now has variable subbase type and thickness, use or non-use of pavement reinforcement, and variable transverse contraction joint spacing. The materials and thicknesses that were used are shown in Table 1. The location of each rigid pavement section can be found in Figure A-1.

As previously mentioned, the flexible test sections are located in the west-bound roadway. All the surviving flexible test sections in Loops 4, 5, and 6, were resurfaced with bituminous concrete (Tables 2 and 4). Two new flexible pavement sections that duplicated original designs were constructed from salvaged materials (Table 3). New flexible pavement sections that represented new designs were constructed with gravel, crushed stone, bituminous-aggregate mixture (BAM) or cement-aggregate mixture (CAM) base courses, and gravel or crushed stone subbases in addition to the regular Road Test sand-gravel subbase mixture. New sections of composite pavement also were constructed that utilized plain paving grade portland cement concrete as base course in conjunction with bituminous concrete surfacing. The new flexible and composite pavement test sections are recorded in Table 3.

In addition to the major variables, a special test of four mineral fillers was constructed in the westbound lanes. The location of the mineral filler test sections is given in Table 7. In the flexible tangent of the new facility, surfacing thickness, type and thickness of subbase, and type and thickness of base course are the principal variables. The flexible pavement experimentation also includes a study of bituminous overlays. The type and thickness variations in each of the designs in the flexible pavement experimentation are presented in Tables 2, 3, and 4. The location of each flexible test section can be found by reference to Figure A-1.

TABLE 7

TEST SECTIONS FOR MINERAL FILLER STUDY IN BITUMINOUS SURFACE

Filler Type	Course	Lane	Section Length (feet)	Westbound Roadway Station
Asbestos Fiber	Binder	North	1762	140+38-158+00
Asbestos	Surface	North	3535	126+65-162+00
Asbestos	Surface	South	2735	126+65-154+00
Hydrated Lime	Surface	North	3241	162+00-194+41
Hydrated Lime	Surface	South	3241	162+00-194+41
Clay (kaolin)	Surface	North	2990	270+60-300+50
Clay (kaolin)	Surface	South	2990	270+60-300+50

Loop 1, which includes replicates of many original Road Test designs, has been used for special tests without interference from traffic as well as for observation. The design of each test section of Loop 1 is shown in Tables 5 and 6. The location of each section can be determined by reference to Figure A-2.

MEASUREMENT PROGRAM

The field measurement program is intended to provide information useful for (1) evaluating the behavior of each pavement test section under normal mixed traffic, (2) determining the effects of experimental variables such as subbase type, base course type, joint spacing, resurfacing and mineral filler variations on pavement behavior, and (3) applying these results to structural design of highway pavements in Illinois and elsewhere.

To achieve the above mentioned goals, condition surveys, rut depth measurements and pavement smoothness measurements with a BPR type roadometer are being made to compute Present Serviceability Index values for each test section. Also, faulting at contraction joints in rigid pavements and static rebound deflection measurements at edges and at corners of rigid pavements and in outer wheelpaths of flexible pavements are being measured annually. Along with these field measurements, machine traffic counters record hourly traffic volumes continuously. Vehicle classification counts are made periodically to determine the number of different types of vehicles that travel in each lane. A limited number of truck-weight surveys have been made at the test site to determine the distribution of axle weights for trucks passing over the test sections. These traffic counts and weight surveys are used to convert mixed traffic loads into 18-kip equivalent single-axle loads passing over test sections.

Periodically, cores have been removed from flexible pavements to evaluate the effect of the different mineral fillers in the bituminous surfacing and from BAM and CAM subbases under the rigid pavement to evaluate their behavior as subbase materials.

ENVIRONMENTAL CONDITIONS

Climate

The climate at the AASHO Road Test site, which is temperate, has been described previously in detail 8/ and only a brief resume is given here. The mean annual summer temperature is 76°F as compared to a mean winter temperature of 27°F. The average annual precipitation is 34 inches, which falls mostly as rain during warm months; however, snowfall averages 25 inches per year.

The soils usually remain frozen from December 15 to March 1, although light freezing at the surface may occur earlier than December 15 and later than March 1. Frost penetrates, on the average, to a depth of 28 inches below the ground surface, and during winter warm spells, the soil may thaw and refreeze at the surface a number of times.

Average monthly temperature and rainfall that prevailed during the reconstruction period are in Table 8. The table shows that the autumn of 1961 and the winter of 1962 were somewhat warmer than normal and had above normal precipitation. During the 1961 autumn construction period, precipitation fell on 24 days, producing an average of 0.32 inch of rain per day, almost 2 inches above normal for the three-month period. In 1962, summer temperatures were about normal; above average precipitation fell in January, February, July, and October, and below normal precipitation fell during the remaining months of the year.

TABLE 8

RECORD OF TEMPERATURE AND PRECIPITATION DURING CONSTRUCTION

Month	Average Monthly Temperature (°F)				Precipitation (inches)		
	Actual		Normal 1/				
	High	Low	High	Low	Actual	Normal 1/	Days of Precipitation
Oct. 1961	66	47	67	43	2.88	1.60	8
Nov.	50	33	50	32	2.22	1.80	6
Dec.	34	18	38	21	2.55	2.40	10
TOTAL					7.65	5.80	24
Jan. 1962	26	9	36	19	2.62	1.95	9
Feb.	34	19	36	22	1.84	1.50	10
Mar.	43	27	46	29	2.67	3.30	9
Apr.	64	40	60	38	1.77	4.30	9
May	80	58	75	50	3.15	3.80	9
June	85	60	84	62	2.02	4.10	8
July	83	63	88	65	5.19	2.98	13
Aug.	87	62	85	62	1.37	2.60	3
Sept.	76	52	78	53	2.11	3.20	5
Oct.	68	47	67	43	2.91	1.60	10
Nov.	52	32	50	32	1.08	1.80	4
TOTAL					26.73	31.13	89

1/ Obtained from local U.S. Weather Bureau records over 10-year period.

Soils

Soils in the area were formed from glacial drift overlain by a thin mantle of loess 40 to 60 inches thick. The drift is variable in composition and thickness. A number of deltaic deposits, some of which furnished granular material for reconstruction, occur in the area. The area that includes the rehabilitated Test Road is gently undulating ground moraine ranging between 605 and 635 feet in elevation. Although several small streams carry runoff drainage into the Illinois River, the area generally has poor natural drainage. The ground moraine was once covered by a shallow glacial lake (elevation 640 feet) caused by backup of glacial melt waters draining out through the Illinois River valley in late Pleistocene time. The glacial drift has a maximum thickness of only 30 feet, and is underlain by sedimentary rocks of Pennsylvanian Age.

The A horizon of soil, which is 1 to 2 feet thick, has been classified as A-6 and A-7-6. The B horizon is a fairly plastic A-7-6 soil and also is 1 to 2 feet thick, while the underlying parent material, C horizon, generally exhibits A-6 characteristics. A detailed description of the soils is included in Highway Research Board Special Report 61B 7/.

MATERIALS AND CONSTRUCTION

This section gives details relative to materials and procedures used in constructing new embankment, subbases, bases, surfaces, and shoulders when the AASHO Test Road was rehabilitated. In many instances, the reader may refer to HRB Special Reports No. 61B and No. 66 for further information about materials and construction procedures used when the original test facility was built.

Construction of the rehabilitated roadway, which began in October 1961 and was completed in December 1962 when it was opened to traffic, involved converting the original test facility into a part of Interstate 80 while retaining as many of the original test sections as feasible. This work included removal of all nonessential test bridges and culverts, turnarounds, and pavement test sections that either failed during testing or did not meet interstate highway design standards.

The surface of turnarounds and dismantled test sections was broken into small pieces, less than 2 sq ft, so that it could be used as fill in approach embankments at new crossroad bridges. The granular base and subbase salvaged from turnarounds and test sections was stockpiled for later use. Each layer of material was removed carefully to avoid contaminating the material being salvaged. The amount of granular material salvaged from unserviceable test sections ranged from partial to complete removal, depending on the pavement design of the new test sections.

Salvaging the embankment soil from the turnarounds was done in two steps. First, the outer embankment, which was the gray A-6 soil under the shoulders (HRB Special Report 61B, p. 14), was removed for use in crossroad embankments. Then, the remaining yellow-brown A-6 soil, which was under the turnaround pavement, was removed for new embankment between test tangents. The major difference between the original and the new roadway embankment is that the new embankment between test tangents is entirely salvaged yellow-brown A-6 soil while the original embankment had a yellow-brown A-6 soil core with gray A-6 soil wedges on both sides to carry the shoulders.

New pavement test sections were constructed on the remains of original base, subbase, and embankment within test tangents and on new embankment between test tangents.

The materials used as subbase in new test sections were salvaged sand-gravel mixture, gravel, crushed stone, BAM, or CAM. The gravel and the crushed stone were new aggregates from sources other than those used in the AASHO Test Road. The BAM and the CAM are bituminous- and cement-stabilized materials that utilized salvaged sand-gravel mixture as the basic aggregate.

The base course, for new flexible test sections, was salvaged crushed stone-special, crushed stone, BAM, CAM, all of which have been previously mentioned, and portland cement concrete (PCC). Plain portland cement concrete was used as base in six test sections where the grade was lowered under existing overhead bridges to maintain adequate clearance.

The materials and the construction procedures used to build the new experimental highway conformed to the requirements of Illinois Standard Specifications for Road and Bridge Construction adopted January 2, 1958, to Supplemental Specifications adopted July 1, 1961, and to the Special Provisions in the Contract Proposal.

Typical cross sections for new rigid pavement are in Figure 3, while typical cross sections for new and rehabilitated bituminous pavement are in Figure 4. The new pavement is 24 feet wide, which is the same width as was the original test pavement.

New embankments were constructed 44 feet wide and 3 feet thick, similar to the original test road design. However, at some locations, where the new pavement was constructed thicker than the original pavement, the embankment surface was lowered to accommodate the added thickness. All embankment side slopes were 4:1 except at a few locations where changes in the shoulder cross section resulted in slight variations from the 4:1 slope. The median ditch is 3 feet deep.

A variety of subbase configurations are present in the new test road. In the eastbound roadway, where only rigid pavements are located, experimental pavements that have been retained from the original road test incorporate subbases that are daylighted at the embankment sideslope beyond the shoulder (Figure 3A). New

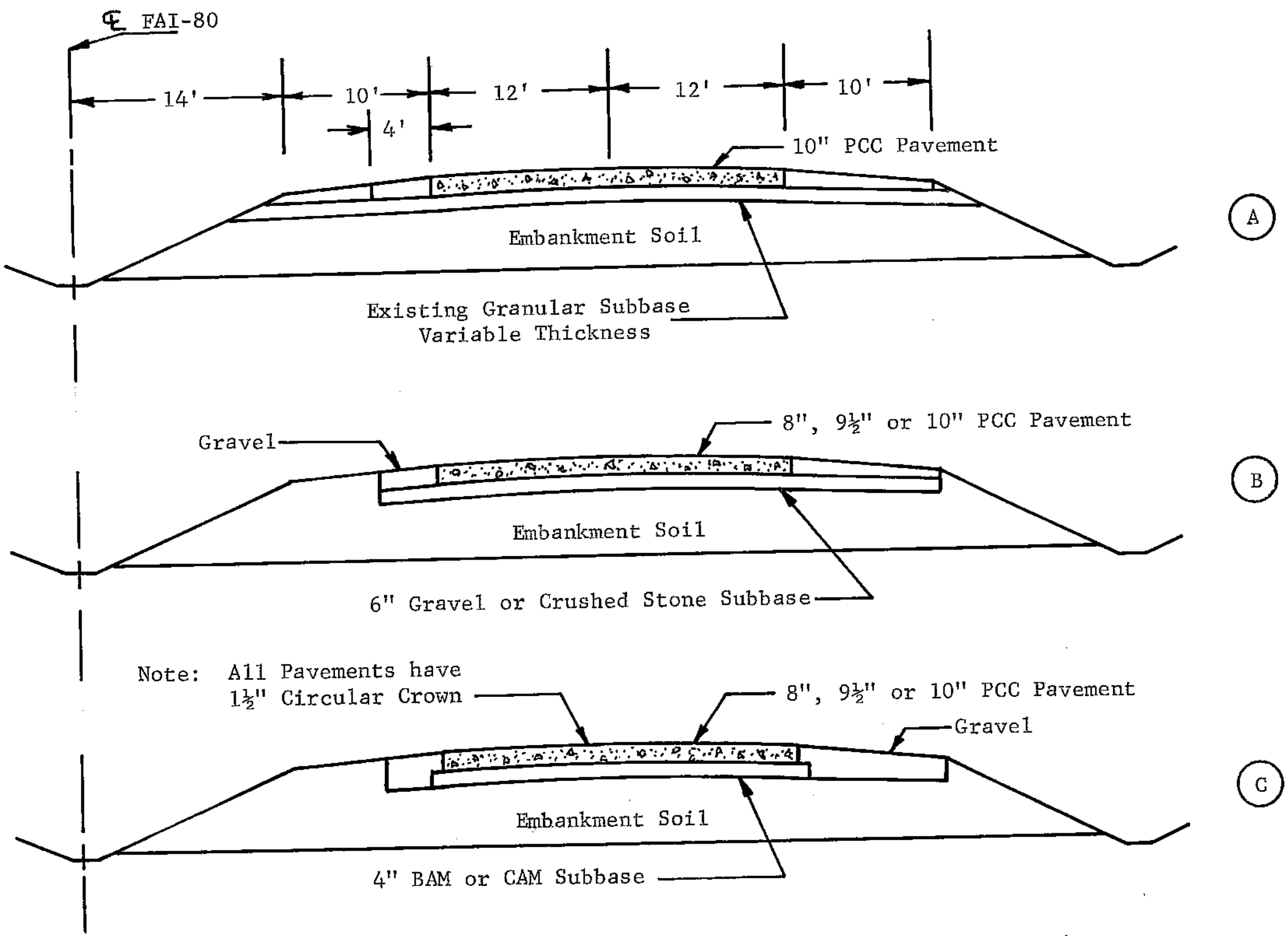

Figure 3. Typical cross sections for new portland cement concrete pavement.

experimental rigid pavements, now serving as connecting links between the original road test tangents and utilizing gravel or crushed stone as subbase, have trenched subbases that extend to the outer edge of the granular shoulders (Figure 3B). As a third variation, new experimental pavements that utilized stabilized granular materials in trench, have 26-foot subbases extending 12 inches beyond either pavement edge under the shoulders (Figure 3C).

In the westbound roadway, where both flexible and compostie pavements are located, all new experimental sections have 26-foot subbases and bases. Only granular materials were used as subbase, but the base courses contained both granular and stabilized materials (Figure 4A). Experimental road test sections that were retained for further testing after resurfacing with bituminous concrete have a cross section like the one in Figure 4B. The cross section of pavement that has a 24-foot PCC base course appears in Figure 4C.

The detailed description of embankment, subbase, base, surface, shoulder, and scale construction which follows is presented in a form similar to that used in HRB Special Report 61B for convenient comparison.

Embankment

The soil used originally in the special 3-ft embankments of the AASHO Road Test was obtained from three borrow pits located adjacent to the right of way (Figure 2). The special requirements and the physical characteristics for the road test embankment soils are described in HRB Special Reports No. 61B and No. 66. As previously mentioned, the gray clay A-6 soil salvaged from the turnarounds was used as embankment material in ramps and in approaches to new crossroad bridges, while the yellow-brown soil salvaged from the turnarounds was used as new roadway embankment between test tangents.

When the grain size distribution of the original yellow-brown soil is compared with the salvaged embankment soil (Figure 5), it indicates that the salvaged soil is finer than the original soil. Moreover, this difference in gradation probably accounts for the difference in optimum moisture, maximum dry density, liquid limit, and plasticity index between the two soils (Table 9). The salvaged embankment was constructed 3 ft thick, to the same lines and grades as the road test embankments. The soil was placed in 6-in. lifts and was adjusted for moisture content when necessary. Each lift was disked to break up oversized clods and was thoroughly mixed to secure a uniform moisture content. Although sheepsfoot rollers were used for the initial pass, final compaction to the required density was achieved generally with four passes of a pneumatic-tired roller. The last lift, which was built slightly above profile grade, was cut to final elevation with a motor grader.

Field density tests for each lift were made at 300-ft intervals to check compaction. Each lift was compacted to a density of 95 to 100 percent of standard dry density as determined by the standard AASHO Designation: T99-49. At each sampling location, a Shelby tube sample was obtained from which the wet density and moisture content were determined, and the field dry density was computed. The field dry densities were compared with maximum dry densities obtained from compacted specimens in the laboratory by the AASHO one-point method developed during construction of the road test and are described in Appendix B of HRB Special Report No. 61B. A summary of embankment compaction test results (Table 10), indicates that the field dry density averaged 103.9 pcf as compared to a mean maximum dry density of 105.4 pcf, which gave a mean field compaction of 98.5 percent.

<u>Subbase - Flexible and Rigid Pavement</u>

Five different materials were used as subbase in rehabilitating the test facility. They were the salvaged sand-gravel mixture, gravel, crushed stone,

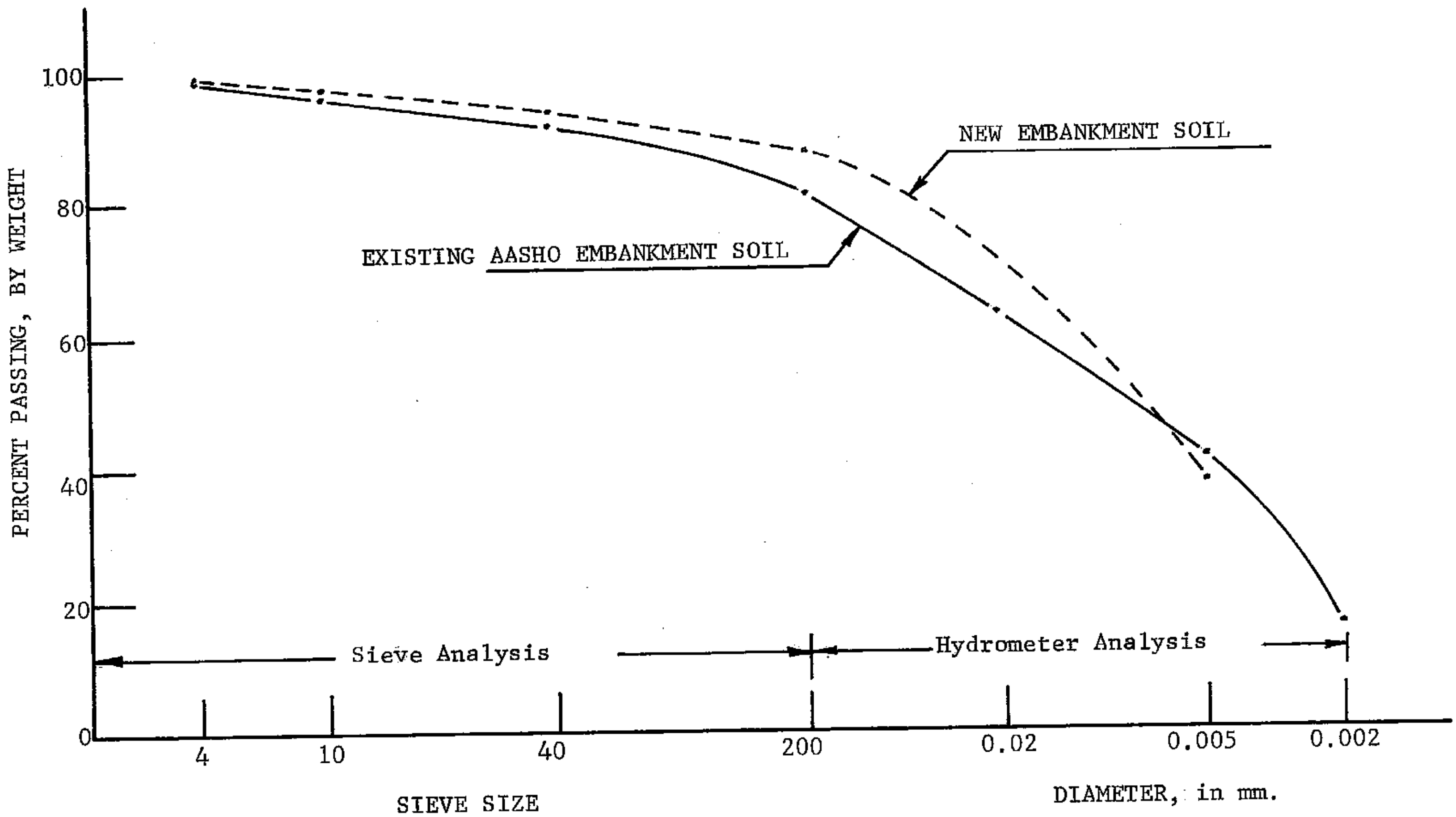

Figure 5. Graph comparing grain size distribution of existing AASHO Embankment Soil with New Embankment Soil.

TABLE 9

PHYSICAL CHARACTERISTICS OF YELLOW-BROWN A-6 SOIL BEFORE AND AFTER SALVAGE

Soil Characteristic	AASHO (1) Designation	Original Soil Mean (2)	Salvaged Soil		
			No. of Tests	Sample Mean	Standard Deviation
Optimum Moisture (percent)	T99-49	15.1	20	17.4	3.9
Maximum Dry Density (pcf)	T99-49	116.4	20	110.4	9.6
Liquid Limit (percent)	T89-54	29.4	188	40.0	9.7
Plasticity Index	T91-54	13.6	187	20.2	4.3
Specific Gravity	T100-54	2.71	42	2.70	0.041
Grain Size Distribution	T88-54				
No. 4		99.0	188	99.4	
10		96.8	188	96.9	
40		91.0	188	93.7	
60		87.7	--	--	
200		80.6	188	87.9	
0.02 mm		62.8	--	--	
0.005 mm		42.3	188	37.3	
0.002 mm		15.3	--	--	
Lab CBR (soaked)		2-4			
Field CBR (spring season)		2-4			
Classification	M-145	A-6		A-6,A-7-6	

(1) 1957 Revisions of AASHO Standard Test procedures were used for testing of the salvaged embankment soil wherever possible.

(2) From Table 7; HRB Special Report No. 61B; page 30.

TABLE 10

SUMMARY OF FIELD COMPACTION TESTS ON SALVAGED EMBANKMENT SOIL

Test	No. of Tests	Sample Mean
Optimum Moisture (percent)	32	19.7
Maximum Dry Density (pcf)	32	105.4
Field Dry Density (pcf)	32	103.9
Field Moisture Content (percent)	32	19.9
Compaction (percent)	32	98.5

bituminous-aggregate mixture, referred to as BAM, and portland cement-aggregate mixture, referred to as CAM.

Originally, the sand-gravel mixture served as a mulch for the embankment, but later it became the subbase common to both flexible and rigid pavements of the AASHO Test Road. The sand-gravel mixture, which was used as subbase in the original testing, was salvaged from dismantled test sections and was stockpiled for later use. The gravel and the crushed stone were dense-graded materials used as subbase by Illinois at that time, while the BAM and the CAM subbase were produced from the salvaged sand-gravel mixture. The number of each test section showing where each type and thickness of subbase was used in the rehabilitated roadway is identified in Tables 1-6 and in Figures A-1 and A-2 in Appendix A.

The following first describes individual materials and construction procedures used for granular subbase, then stabilized materials and construction procedures are described.

The original sand-gravel mixture was prepared from washed gravel, silica sand, and overburden soil, all which were obtained from a deposit located just west of the project. After the gravel was washed and screened, silica sand and fine-grained brown silt loam overburden soil from the same deposit were mixed together to produce a material that met the requirements for subbase of both the rigid and the flexible pavements. Specification limits, gradation formulas and tolerances, and mean gradation of the sand-gravel mixture, in place, are compared with the salvaged material in Table 11, which indicates only a slight difference in gradation between the original and the salvaged material. The original sand-gravel mixture had a mean CBR value of 34.7, ranging between 18 and 54 at 0.1 inch penetration, and the material passing the No. 40 sieve was non-plastic. Further information about the sand-gravel mixture is given on pages 47, 48, and 55 in HRB Special Report No. 61B 2/.

TABLE 11

SUMMARY OF GRADATION TEST OF SAND-GRAVEL SUBBASE IN PLACE AND FROM SALVAGED MATERIAL IN STOCKPILES

	Percent Passing		Mean Percent Passing	
Sieve Size	Specification Limits	Gradation Formula and Tolerances (1)	Material in Place (2)	After Salvage
1-1/2 in.	100	100	100	--
1 in.	95-100	95-100	100	100
3/4 in.	90-100	95±5	96.9	94
1/2 in.	80-100	90±5	89.7	87
No. 4	55-100	73±5	71.2	72
No. 10	40-80	54±5	--	54
No. 40	10-30	27±3	27.0	27
No. 200	5-9	7±2	7.5	8.2

(1) From Table 16, HRB Special Report 61B, page 47.

(2) From Table 21, HRB Special Report 61B, page 56.

Shook and Fang 5/ reported test results of mineralogical composition and physical properties of the sand-gravel subbase conducted during the road test cooperative testing program.

The salvaged sand-gravel mixture was the primary subbase material used in the rehabilitated road test. Altogether, 23 flexible and 55 rigid test sections utilized the sand-gravel mixture as subbase. Of the 78 test sections, all but two contained salvaged material while the other two contained a sand-gravel mixture that had been stockpiled but not used during the original road test.

Gravel, which was not used in the AASHO Test Road, was produced in accordance with Illinois specifications and was used as the subbase in 15 new rigid and 14 new flexible test sections which are listed in Tables 1, 2, 3, and 4. All new flexible test sections with a stabilized base also were placed on gravel subbase.

The gravel was obtained from local pits near Utica, Illinois and Ottawa, Illinois, and was trucked directly to the jobsite for placement and compaction. A summary of mean gradations from the three local pits is in Table 12. When the mean gradations of the gravel are compared with the sand-gravel mixture (Table 11), 72 percent of sand-gravel mixture passed the No. 4 sieve as contrasted to 50 to 59 percent for the gravel, which indicates the gravel is a coarser material.

Crushed Stone was used as a subbase material in four new portland cement concrete test sections (Tables 1 and 2). Specification limits and mean gradation of the crushed stone, which was hauled in trucks from the quarry at Troy Grove, Illinois, directly to the jobsite, are shown in Table 13.

With few exceptions, procedures for constructing the granular subbase for rigid pavement were similar to those for flexible pavement. Water was added to the sand-gravel mixture, gravel, and crushed stone at a central mixing plant so that the material contained sufficient water to provide the maximum compaction.

TABLE 12

SUMMARY OF GRADATION TESTS OF GRAVEL SUBBASE MATERIAL

Sieve Size	Percent Passing Specification Limits	Mean Percent Passing Hess Pit	Garrow Pit	Ryburn Pit
1 in.	100	100	100	100
3/4 in.	80-100	94	94	93
1/2 in.	65-100	83	82	73
No. 4	40-60	59	57	50
No. 8	25-50	42	42	42
No. 40	15-25	16	17	19
No. 200	5-10	7	9	7
P. I.	4-9	5.5	6.2	5.3

TABLE 13

SUMMARY OF GRADATION TESTS OF CRUSHED STONE SUBBASE MATERIAL

Sieve Size	Percent Passing Specification Limits	Mean Percent Passing Sample
1 in.	100	100
1/2 in.	60-90	80
No. 4	40-60	53
No. 8	25-50	40
No. 16	20-40	30
No. 200	5-15	11

The contractor hauled the moistened material in trucks to the jobsite where the aggregate was deposited in a spreader box mounted on a track-type tractor. After placing the loose material in 13-ft-wide lifts sufficiently thick to produce a 3- or 4-in. compacted layer, the subbase was compacted to not less than 100 percent of maximum dry density (AASHO Designation: T99-57) of the material. If the moisture content was insufficient to obtain this compaction, water was added to the aggregate in place until satisfactory compaction was achieved.

Vibratory compactors, similar to those used in constructing the AASHO Test Road, followed the spreader and compacted the loose aggregate to lines, grades, and cross sections shown on the plans. Usually, a single pass of the vibratory compactor was sufficient to meet the required density. Field density tests were obtained by the Sand Cone Method (AASHO Designation: T147-54) at 100-ft intervals, and were compared with the laboratory maximum dry density to determine the percent compaction. Density tests for the three kinds of granular subbase are summarized in Table 14. When subbase thickness exceeded a single 4-in. (compacted) lift, additional lifts were placed until the required thickness was achieved.

When existing in-place granular materials were used as subbase for a new base coarse, the top 2 inches was loosened, wetted, and shaped 26 feet wide for its entire length. In some cases where the existing subbase was slightly below grade, additional material was added to the already loosened material and was compacted by a vibratory compactor.

In rigid pavement test sections, the final surface was placed slightly above grade so that after forms were set the subbase could be cut to final grade with a mechanical subgrader operating on the forms. After trimming the subbase, it was rolled with a tandem roller. However, the subbase surface in the flexible sections was trimmed and shaped to final grade with a motor grader and was rolled with a

TABLE 14

SUMMARY OF FIELD COMPACTION TESTS ON GRANULAR SUBBASES

Test	Crushed Stone	Gravel	Sand-Gravel Mixture
Mean Dry Density (pcf)	138.5	137.7	138.8
Mean Optimum Moisture (percent)	7.1	7.2	7.7
Mean Field Dry Density (pcf)	140.3	140.1	139.2
Mean Field Moisture Content (percent)	6.3	6.4	6.8
Mean Compaction (percent)	101.3	101.3	100.2

tandem roller. After completing the pavement, the subbase was extended beyond the pavement edge in a manner previously explained (Figures 4 and 5).

The bituminous-aggregate mixture (BAM), which was used as a 4-in. subbase in five rigid test sections which are identified in Table 1, is similar to the bituminous-stabilized base described on page 74 in HRB Special Report 61B.

The mixing formula and bitumen content established for the BAM are shown in Table 15. The Special Provisions required that the asphalt content of the BAM should be neither less than 5 percent nor more than 6.5 percent. The design asphalt content, 5.7 percent, was selected on the basis of Marshall tests, and the Marshall stability and flow values for the design mixture were 1590 lbs and 5.6 respectively. During construction, the proportions of the mixing formula were adjusted slightly from those used in the laboratory testing (Table 15) because of small variations in the original samples. The asphalt content was lowered from 5.7 percent used in the laboratory test to 5.2 percent for the mixture used in the field. Furthermore, the special provisions required that the permissible variation from the established asphalt content should be plus or minus 0.3 percent.

A summary of Extraction tests and Marshall tests on BAM samples taken at the plant during production are shown in Table 16. The mean Marshall stability and flow values were 1370 lbs and 11.0 respectively.

BAM was produced by combining 85 to 100 penetration grade paving asphalt with the salvaged sand-gravel mixture in an automatic batch-type plant located near the west end of the project. The mixture was delivered in trucks from the plant to the jobsite where it was deposited in an asphalt paver at a temperature between 250 and 325^{o}F.

TABLE 15

MIXING FORMULA FOR BAM

Sieve Size (% Passing)	Original Mixing Formula (% by Weight)	Adjusted Formula (% by Weight)
1 in.	100	100
3/4 in.	98.5	99
1/2 in.	91.8	93
No. 4	73.0	73
No. 10	55.3	48
No. 40	29.0	24
No. 200	7.4	9.3
Bitumen	5.7	5.2

TABLE 16

SUMMARY OF EXTRACTION TESTS AND MARSHALL TESTS ON BAM

Item	Specification Limits	Extraction Tests (mean)	Marshall Tests (mean)
Percent Passing:			
1 in.	95-100	100	
3/4 in.	90-100	96.5	
1/2 in.	80-100	89.7	
No. 4	55-100	69.6	
No. 10	40-80	51.2	
No. 40	10-30	15.7	
No. 80	--	8.9	
No. 200	0-9	5.3	
Bitumen (percent)	5.0-6.5	5.2	
Stability			1370
Flow (0.01 in.)			11.0
Specific Gravity of Briquette (d)			2.42
Theoretical Specific Gravity (D)			2.46
Percent Air			1.71

As the paver moved forward, the BAM subbase was placed in 13-ft-wide lifts sufficiently thick to produce a 2-in. compacted thickness. The thickness of each lift was regulated by the paver's screed which was controlled electronically by a grade reference sensor. The sensor followed a steel wire supported by steel pins that were set at 25-ft centers. When paving adjacent to a previously compacted lift, the thickness was controlled by the sensor resting on a long ski sliding on the compacted surface.

The Special Provisions required that the finishing machine strike a finish that is smooth, true in cross section, and free from transverse hollows and imperfections, and that no more than two 2-in. lifts be placed on the same day. Each lift was compacted immediately to a required density by one pass of a three-wheel roller followed by several passes of a pneumatic-tired roller. Final rolling was done with a tandem roller. The Special Provisions required that each lift of BAM be compacted to 95 percent of the theoretical maximum density of a voidless mixture. To check the compacted density, cores were removed from each lift at 250-ft intervals at selected sites. The mean compacted density achieved was 94.8 percent.

The cement-aggregate mixture (CAM), which served as a 4-in. subbase under five rigid pavement test sections during rehabilitation, is the same material that was described as cement-treated base on page 74 in HRB Special Report 61B, except that the sand-gravel mixture used as the aggregate was salvaged material. The five rigid pavement test sections with a CAM subbase are identified in Table 1.

The Special Provisions required that the CAM have a minimum compressive strength of 650 psi at seven days and not contain less than 4 percent nor more than 5 percent portland cement. Laboratory tests indicated that the mix design for CAM contain 4 percent (by weight) cement and 8 percent (by weight) moisture, and have a maximum dry density of 137.7 pcf.

The salvaged sand-gravel mixture, Type I portland cement, and water were mixed for at least 30 second in a batch-type mixing plant located near the center of the project. After mixing, the CAM was hauled to the jobsite in trucks and was deposited in an asphalt paving machine which spread a 13-ft-wide lift sufficiently thick to produce a layer not less than 4 inches nor greater than 5 inches when compacted. The Special Provisions required that the total time lapse between the time water was added to the mixture until the mixture was deposited and spread on the moistened subgrade be no greater than 30 minutes. Moreover, the mixture had to be compacted within 2 1/2 hours after the water was added.

Immediately following placement, the loose CAM was compacted with a vibratory compactor, a small tamping roller, and a tandem roller. The Special Provisions required that the density of the compacted lift be not more than 5 lbs below maximum dry density as determined according to ASTM Designation: D698-56T, Method C. A summary of field density and of compressive strength tests is given in Table 17. The CAM subbase had a mean field wet density of 150.1 pcf and a mean 7-day compressive strength of 746 psi.

After the top layer of CAM was compacted, the surface was rolled with a tandem roller, until it was smooth, closely knit, and free from cracks, ridges, and depressions. The surface was then checked for crown and grade. Areas that were more than one half inch below grade were raised with fresh CAM while areas that were more than one half inch above grade were removed and wasted.

After final rolling, the compacted surface was sealed by spraying 0.2 gallons per square yard of rapid curing liquid asphalt on the surface as a curing coat.

Base Course - Flexible Pavement

Crushed stone-special, salvaged crushed stone-spreal, crushed stone, BAM, CAM, and plain portland cement concrete were the materials that served as base for

TABLE 17

SUMMARY OF FIELD DENSITY AND COMPRESSIVE STRENGTH TESTS ON CAM

Test 1/	No. of Tests	Mean	Standard Deviation
Laboratory Wet Density (pcf)	38	148.0	2.7
Field Wet Density (pcf)	43	150.1	4.2
Compressive Strength (psi)			
7 - Day	27	746	143
14 - Day	2	926	--

1/ Optimum moisture and maximum dry density determined by AASHO standard procedure (AASHO Designation: T99-57).

flexible pavement in the rehabilitated AASHO Test Road. Test sections containing crushed stone-special became a part of the rehabilitated facility when 17 of the original test sections were resurfaced with bituminous concrete. For a description of this material, the reader may refer to Special Report 61B, Chapter 4, p. 63.

Sufficient salvaged crushed stone-special was recovered when the test loops were dismantled to construct two new test sections containing this material. The original crushed stone, which was obtained near Lockport, Illinois, was dolomitic limestone which had a 7 percent loss after 5 cycles of the sodium sulphate test (AASHO Designation: T104-56) and which had a mean California Bearing Ratio (CBR) of 107.7. A sample gradation of the original material may be seen in Table 18.

The construction procedures used for placing the salvaged crushed stone were the same as those previously described for granular subbase in this report. A summary of field density tests (Table 19), showed that the salvaged crushed stone-special was compacted at 100.3 percent of maximum dry density.

Crushed Stone, which is used regularly as base material in Illinois, was selected as base material in one new flexible test section. The crushed stone, which is limestone, was obtained from a quarry at Troy Grove, Illinois, 11 miles northwest of the test site.

As can be seen from the gradation tests in Table 18, the crushed stone is a finer dense-graded material than the crushed stone-special used as base in the original experiment.

The crushed stone, which had a maximum dry density of 138.5 pcf, was delivered in trucks to the jobsite where it was deposited at an optimum moisture content of 7.1 percent in a spreader. The construction procedures used for placing the crushed stone were the same as those previously described for granular subbases in this

TABLE 18

SUMMARY OF PLANT GRADATIONS OF CRUSHED STONE BASE COURSE - SPECIAL

	Mean Percent Passing [1/]	
Sieve Size	Crushed Stone Special [2/]	Crushed Stone
1-1/2 in.	100	--
1 in.	90	100
3/4 in.	81	--
1/2 in.	68	80
No. 4	48	53
No. 8	--	40
No. 10	35	--
No. 16	--	30
No. 40	20	--
No. 100	13.5	--
No. 200	10	11

[1/] AASHO Designation: T27-46

[2/] From HRB Report 61B, Table 28, page 64

TABLE 19

SUMMARY OF FIELD DENSITY TESTS ON CRUSHED STONE AND SALVAGED CRUSHED STONE - SPECIAL

Test	Salvaged Crushed Stone, Special (mean)	Crushed Stone (mean)
Maximum Dry Density (pcf)	138.6	138.5
Optimum Moisture (percent)	7.0	7.1
Field Dry Density (pcf)	139.1	140.3
Field Moisture Content (percent)	6.1	6.3
Compaction (percent)	100.3	101.3

report. In the summary of field density tests (Table 19), the mean compaction of the crushed stone was determined to be 101.3 percent of the maximum dry density.

Bituminous-aggregate mixture (BAM), which was described previously as subbase, was used as a base in six new flexible sections. Of the six test section, two had 8-in.-thick bases, three had 10-in.-thick bases, and one had a 12-in.-thick base. The complete design for each test section is in Table 3, while their location is shown in Figure A-1 of the Appendix.

Cement-aggregate mixture (CAM), which like the BAM was described previously in the subbase section, served as a base in seven new flexible test sections. The location of each test section can be seen in Figure A-1 of the Appendix, while the design of each test section is listed in Table 3. CAM bases were 10, 12, and 14 in. thick. Of the seven test sections, two were 10 in. thick, four were 12 in. thick, and one was 14 in. thick.

Plain portland cement concrete PCC served as a base in six new composite pavement test sections that are located under the overhead bridges which carry local traffic over Interstate 80. Three of the six test sections have an 8-in.-thick base, while the remaining three have a 9.5-in.-thick base. The PCC base course was placed on a granular subbase of either sand-gravel mixture or crushed stone-special or crushed stone whose thicknesses varied depending on the amount of grading required for the base.

All materials used in the PCC base were the same as those reported under portland cement concrete in the Pavement Surfacing section which follows this section.

Pavement Surfacing - Flexible and Rigid

As in the original AASHO Test Road, the rehabilitated test road contains both flexible and rigid pavement surfaces. All flexible pavement surfaces are in the westbound roadway while rigid pavement surfaces are in both the eastbound and westbound roadway.

Of the 43 flexible test sections that have a bituminous surface, 21 were remaining test sections which were resurfaced, while 22 were new test sections. New flexible test sections received a binder and a surface course of bituminous concrete; however, the resurfaced test sections required a leveling binder course to eliminate surface irregularities between and within test sections before placing the binder and the surface courses.

As a side study, the bituminous concrete surfacing in several test sections was altered either by adding asbestos fiber to the mix or by substituting hydrated lime and kaolin clay for the standard limestone dust as mineral filler. As previously mentioned, Little reported the results of the mineral filler experiment in a separate report 6/.

Because all pavement in Loop 3 was inadequate for interstate traffic, all flexible and rigid test sections were removed and were replaced with a 10-in. reinforced PCC surface containing sawed dowelled contraction joints at 100-ft intervals. The new PCC pavement in the eastbound roadway was placed on new BAM, CAM, and Gravel subbase, while the new pavement in the westbound roadway was placed on various kinds and thicknesses of existing granular subbase.

In addition to original rigid pavement test sections which were retained for further testing, new 10-in. reinforced PCC pavement containing sawed dowelled contraction joints at 100-ft intervals replaced original test sections in Loops 4, 5, and 6 that failed or that were inadequate for interstate traffic in the eastbound roadway.

The following describes in detail the portland cement and the bituminous concrete used as surfacing in the rehabilitated test facility.

Portland Cement Concrete, which contained coarse aggregate, a natural sand, Type IA Air-Entraining portland cement, water, and an air-entraining agent, served as a surface in 37 new rigid test sections. The coarse aggregate, which was gravel, was obtained in two sizes, Size LA (2 1/2 in. maximum) and Size B (1 in. maximum), from a pit near Sheridan, Illinois. Both sizes were blended in equal proportions to obtain the desired gradation. Sample gradations and specification limits for the coarse aggregate are in Table 20.

The fine aggregate, which was a blend of torpedo sand from a pit near Buffalo Rock and of fine sand from a local deposit in Section 5 of T33N, R1E of the Third Principal Meridian, LaSalle County, had a sample gradation and specification limit shown in Table 21. All aggregates were hauled in trucks to the jobsite where they were placed in separate stockpiles until they were needed. In addition to gradation, the fine and coarse aggregates had physical and lithological characteristics similar to those in the original Test Road (Table 22).

The Type IA Air-Entraining Portland Cement was obtained at Oglesby, Illinois, 8 miles southwest of the west end of the project. The cement had an Autoclave Expansion which ranged from 0.08 to 0.16 percent and an Air Content of Mortar which ranged from 18.5 to 19.5 percent according to tests described in ASTM Designation: C175.

Mixing water approved for use in portland cement concrete was obtained from borrow pit No. 3 (Figure 2) which is located at the east end of the project.

The mix design per bag of cement (Table 23) was based on a theoretical cement content of 1.43 bbl per cubic yard, on a water content of 5.1 gal per bag, and about one third sand to total aggregate ratio. The specifications required that the cement, aggregates, and water be proportioned by weight to produce a workable plastic concrete that contains at least 4 percent but not more than 6 percent entrained air, and that has a minimum compressive strength of 3500 psi and a minimum modulus of rupture of 650 psi at 14 days.

TABLE 20

TYPICAL GRADATIONS FOR PCC COARSE AGGREGATE

	Gradation, Percent Passing			
	Specification Limits 1/		Sample	
Sieve Size	Size LA	Size B	Size LA	Size B
2-1/2 in.	100		100	
2 in.	90-100		100	
1-1/2 in.	35-70	100	64	100
1 in.	0-15	90-100	6	100
3/4 in.	0-5	--	2	94
1/2 in.		25-60	0.4	39
3/8 in.		--	--	18
No. 4		0-10	--	2

1/ Article 118.2 (e) of Illinois Standard Specification for Road and Bridge Construction adopted January 2, 1958.

TABLE 21

TYPICAL GRADATIONS FOR PCC FINE AGGREGATE

Sieve Size	Gradation, Percent Passing: Specification Limits 1/	Gradation, Percent Passing: Sample
3/8 in.	100	--
No. 4	90-100	100
No. 8	--	86
No. 16	40-80	63
No. 30	--	41
No. 50	15-30	19
No. 100	0-10	3
No. 200	--	1

1/ Article 117.2 (d) of Illinois Standard Specifications for Road and Bridge Construction adopted January 2, 1958.

TABLE 22

PHYSICAL AND LITHOLOGICAL CHARACTERISTICS OF PCC AGGREGATES

Characteristic	Aggregate: Coarse, Size LA	Aggregate: Coarse, Size B	Aggregate: Fine
Specific Gravity - dry	2.68	2.65	2.63
Specific Gravity - surface dry	2.72	2.71	2.66
Absorption (percent)	1.7	2.1	--
Abrasion Loss (percent)	28.4	26.5	--
Soundness (percent) (ASTM Design: C88)[1/]	12.1	10.0	--
Soft & Semi-Soft Aggregate (percent)	3.1	1.6	--
Chert (percent)	--	1.3	--

[1/] Conforms to requirements of Section 118.2 of Illinois Standard Specifications for Road and Bridge Construction adopted in January 1958.

TABLE 23

PORTLAND CEMENT CONCRETE PROPORTIONS PER BAG OF CEMENT

Characteristics	Quantity
Mixing Water (gal.)	5.1
Absolute Volume (cu ft)	
Sand	1.11
Coarse Aggregate	2.21
Mortar (cu ft)	2.51
Yield (cu ft)	4.72
Porportioning Weights (lbs)	
Sand	193.9
Coarse Aggregate - Size LA	185.4
Coarse Aggregate - Size B	185.4

Because the air content ran slightly below the 5 percent design value, Darex air-entraining agent was added at 8 to 12 oz per cu yd of concrete during mixing to achieve the desired air content. The consistency of the concrete was such that the slump ranged from 3/4 to 1 1/2 in.

Dowel bars, tie bars, and pavement fabric which were used in the concrete pavement met the requirements of the Standard Specifications, except that the pavement fabric used in the new 8- and 9.5-in. replicate test sections was the same that was used in the original AASHO Test Road. Details of pavement fabric and dowel bar assemblies are listed in Table 24.

All dry materials were hauled to the jobsite where they were stockpiled at the batching plant which was located near the center of the project. The cement, coarse aggregates, sand, and water were proportioned in 37.4 cu ft batches (Table 25). The cement and aggregates were hauled to the mixer in trucks which had four-batch compartments.

The portland cement concrete was mixed in 34-E dual-drum paving mixers equipped with a boom and bucket. The specifications required that the mixing time, after all materials except water are in the drum, be not less than one minute. After mixing, the concrete was deposited on the moistened subbase in successive batches in such manner that required little rehandling.

The concrete for the lower course was spread mechanically. Following placement of the pavement fabric, a mechanical spreader was used to spread the concrete for the top course. The specifications required that not more than 15 minutes be allowed to elapse from the time that the first course was deposited on the subbase until the top course was placed. The concrete was finished by the vibratory method.

After the concrete was struck off and consolidated, the specification required longitudinal floating, straightedging, belting, edging, and dragging with a double

TABLE 24

DETAILS OF PAVEMENT FABRIC AND DOWEL BARS IN PCC PAVEMENT

Location	Pavement Thickness	Transverse Joints: Dowels (Smooth) Diameter (in.)	Transverse Joints: Dowels (Smooth) Length (in.)	Transverse Joints: Sawing Depth (in.)	Pavement Fabric: Style [1/]	Pavement Fabric: Weight (lbs/100 sq ft)	Pavement Fabric: Depth (in.)
Loop 1 only	2.5	3/8	12	3/4	66-1010	21	1-1/4
Loop 1 only	5.0	5/8	12	1-1/4	612-66	32	2
Old & New Pavements	8.0	1	18	1-3/4	612-33	51	2
Old & New Pavements	9.5	1-1/4	18	2	612-22	59	2
New Pavement Only	10.0	1	18	2-3/4	612-004	78	2-1/2
Old Pavements	11.0	1-3/8	18	2-1/4	612-11	69	2
Old Pavements	12.5	1-5/8	18	2-1/2	612-00	81	2

[1/] Fabric Style Code: 6 12 6 6

- 6 (fourth) — transverse wire gage
- 6 (third) — longitudinal wire gage
- 12 — transverse wire spacing
- 6 (first) — longitudinal wire spacing

TABLE 25

QUANTITIES OF PORTLAND CEMENT CONCRETE MATERIALS PER BATCH

Material	Quantity
Cement (Type 1A)	7.92 bags
Sand	1536 lbs
Coarse Aggregate - Size LA	1468 lbs
Coarse Aggregate - Size B	1468 lbs
Water (added at the mixer)	33.1 gals (theo.)
Yield (by test)	36.4 cu ft
Cement Factor (theo.)	1.43 bbl/cu yd
Cement Factor (actual)	1.46 bbl/cu yd

thickness of burlap. As soon as the surface sheen disappeared, the finished concrete was covered with white polyethylene sheeting for a curing period of at least 72 hours.

Within 6 to 30 hours after the concrete was placed, transverse contraction joints were sawed by machine which traveled on the forms; however, sawing the longitudinal center joint was delayed until the polyethylene sheeting was removed. All sawed joints were sealed with cold-applied rubber-asphalt joint sealant.

Bituminous Concrete surfacing comprised of a binder and surface course, except where a leveling binder course was required for resurfaced test sections, was utilized in 22 new flexible test sections and in 21 original AASHO flexible test sections.

The aggregates used in the bituminous concrete mixtures were a crushed dolomitic limestone coarse aggregate, furnished in two sizes, from Troy Grove, Illinois, a natural siliceous coarse sand from Ottawa, Illinois, and a natural siliceous fine blend sand from Utica, Illinois. Both fine and coarse aggregate were hauled in trucks to the jobsite where they were stored in stockpiles until they were needed.

Limestone dust representing mineral fillers usually furnished by contractors under the Illinois Standard Specifications was obtained from a processor at Pontiac, Illinois. Specification limits and a typical gradation of fine and coarse aggregate and of mineral filler are listed in Table 26.

The bituminous concrete binder course and surface course mixtures were composed of fine and coarse aggregates and mineral filler combined with 85 to 100 penetration grade asphalt. The paving asphalt used in the bituminous concrete mixtures was PA-5, which had a specific gravity of 1.016 at $60^{\circ}F$ and a penetration ranging from 90 to 98 at $77^{\circ}F$, and was delivered from Seneca, Illinois, in tank trucks. Specifications

TABLE 26

TYPICAL GRADATIONS OF AGGREGATE AND MINERAL FILLER FOR BITUMINOUS CONCRETE

	Gradation, Percent Passing				
	Coarse Aggregate		Fine Aggregate		
Sieve Size	Binder Size A	Surface	Coarse Sand	Blend Sand	Mineral Filler
1 in.	100				
3/4 in.	84				
1/2 in.	42	98			
3/8 in.	--	71			
No. 4	--	23	100		
No. 10	2.0	1.3	67	100	
No. 30			--	--	100
No. 40			21	99.5	--
No. 80			6	49	--
No. 100			--	--	97
No. 200			1.6	1.9	91.6

for this grade asphalt, and typical test results for asphalt used on this project, are listed in Table 27.

The bituminous concrete mixtures were composed of materials controlled, designed, and mixed under the requirements of the standard specifications. General gradation and bitumen content specifications for these mixtures are shown in Table 28. The specific mixtures for this project were designed by the Illinois Division of Highways by the Marshall method, using materials submitted by the contractor as representative of those he intended to use. The mixing formulas and bitumen content established for the project, the allowable tolerances, and typical compositions of mixtures furnished on the project, are shown in Table 29. The design asphalt contents were selected on the basis of Marshall tests. The Marshall stability and flow values for the design mixture were determined to be as follows:

Mixture	Marshall Stability (lbs)	Marshall Flow, 140F (0.01 in.)
Binder Course	1900	8.2
Surface Course	2100	8.3

Laboratory analysis indicated that the constituent aggregates, filler material, and asphalt combined in the following proportions based on percent of total weight of mixture could be expected to produce the design compositions of Table 29:

Material	Binder Course, percent	Surface Course, percent
Coarse aggregate	53.0	53.0
Fine aggregate, coarse fraction	25.7	25.6
Fine aggregate, blend sand	12.8	12.8
Mineral filler (limestone dust)	3.5	3.1
Bitumen	5.0	5.5

In part of the experimental surface course mixture, hydrated lime and kaolin clay were substituted for standard limestone dust mineral filler. The hydrated lime conformed to the requirements of ASTM Designation: 6207-49 Type N Mason's Lime.

TABLE 27

ASPHALT SPECIFICATIONS AND TYPICAL TEST VALUES

Test	Specifications for PA-5	Typical Test Values
Flash point (Cleveland open cup), F	450+	625
Penetration at 77F, 100 g, 5 sec	85-100	91
Loss on heating at 325F, 50 g, 5 hrs, %	1.0-	--
Penetration at 77F, 100 g, 5 sec, of asphalt after heating at 325F, as compared with penetration of asphalt before heating, %	70.0+	--
Ductility at 77F, cm	100+	150
Bitumen soluble in carbon tetrachloride, %	99.6	99.88

TABLE 28

MIXTURE GRADATION SPECIFICATIONS FOR BITUMINOUS SURFACE

Sieve Size: Passing	Sieve Size: Retained	Specification Limits (% by weight)	
		Binder Course	
1 in.		95-100	
1 in.	1/2 in.	20-40	
1/2 in.	No. 4	10-30	20-40
No. 4	No. 10	5-15	
No. 10	No. 40	7-22	20-35
No. 40	No. 80	5-18	
No. 80	No. 200	3-10	
No. 200		3-7	
Bitumen		3.5-7.0	
		Surface Course	
1/2 in.		95-100	
1/2 in.	No. 4	25-50	
No. 4	No. 10	10-30	
No. 10	No. 40	7-22	
No. 40	No. 80	5-18	
No. 80	No. 200	3-10	
No. 200		3-7	
Bitumen		4.0-7.0	

Note: Aggregate percentages based on total dry weight of aggregate; bitumen percentages based on total weight of mixture.

TABLE 29

MIXING FORMULAS AND TYPICAL MIXTURES FOR BITUMINOUS SURFACES

Passing	Retained	Mixing Formula (% by weight)	Mixture Tolerance (% by weight)	Typical Composition (% by weight)
		Binder Course		
1 in.	3/4 in.	9.0 / 21.0] 30.0	± 5.0	29.9
1/2 in.	No. 4	22.0] 30.0	± 5.0	23.7
No. 4	No. 10	8.0		8.0
No. 10	No. 40	13.4] 30.0		10.2
No. 40	No. 80	11.2	± 3.0	14.5
No. 80	No. 200	5.4		4.8
No. 200		5.0		4.1
Bitumen		5.0	± 0.3	4.8
		Surface Course		
1/2 in.	No. 4	35.0] 57.0	± 3.0	33.3
No. 4	No. 10	22.0		25.7
No. 10	No. 40	14.5] 32.0		14.1
No. 40	No. 80	11.3	± 3.0	9.6
No. 80	No. 200	6.2		4.8
No. 200		5.5	± 1.5	7.0
Bitumen		5.5	± 0.3	5.5

The kaolin clay, which was slightly coarser than limestone dust, was a pulverized natural mineral obtained from a supplier at Joliet, Illinois, and was essentially a non-plastic material. Also, asbestos fiber was added to part of the experimental surface course and binder course mixtures. The asbestos fiber furnished by the Johns-Manville Company of Manville, New Jersey, was Canadian Chrysotile Fiber Grade 7M, Quebec Standard Test, Quebec Asbestos Manufacturers Association. The asbestos fiber was used in combination with the standard limestone dust. For equivalent workability, it was necessary to increase the asphalt contents of the mixes containing asbestos fiber by 1.2 percent. Other portions of the mixes were adjusted accordingly to accommodate the asphalt content increase 6/.

During construction, the proportions of the constituent aggregates and mineral fillers were changed slightly from those used in the original laboratory testing because of small variations from the original material samples. The changes were made to meet the mixing formula. The mineral filler content was set at 2.5 percent of the total weight of the mixture for limestone dust and for hydrated lime fillers, as compared with 3.1 percent in the design mixture. The kaolin clay was set at 3.0 percent. The asbestos fiber content was set at 2.0 percent, which was in addition to the 2.5 percent limestone dust also included in the mixture. The asphalt content was raised from 5.5 percent used in the other surface course mixtures to 6.7 percent for the mixture containing the asbestos fiber. An additional 1.2 percent of asphalt was used also in the binder course mixture containing asbestos fiber.

Prior to placing asphaltic mix, the existing base was primed with a light coat of rapid-curing cutback asphalt (Grade RC-0). The aggregates, which were stockpiled at the plant, were continually fed into two cylindrical driers operating in tandem. The hot aggregates were separated into four sizes in the gradation unit. Then, aggregate, mineral filler, and asphalt were proportioned by weight into 5000-lb batches. The heated mixture was mixed dry for 15 seconds before asphalt was added, and wet mixing was continued for another 30 seconds for a total mixing time of 45 seconds per batch. The temperature of the surface and the binder mixture leaving the plant was set at 310°F and 300°F, respectively.

Samples taken from regular plant production and tested by the Marshall procedure showed the test values presented in Table 30. It will be noted that, at least for the single sample taken from the surface course mixture containing the asbestos fiber filler, the Marshall stability was appreciably lower and the flow higher than those test values for the other samples taken.

The bituminous material, which was delivered in trucks, arrived at the paving site at 280°F and was deposited in the hopper of the asphalt paver. The asphalt paver deposited the mixture in 12-ft-wide lanes. The paver screed, which controls the thickness of each lift, was controlled by an electronic sensing device which followed a steel wire supported on steel pins at 25-ft centers. When paving adjacent to a previously paved surface, the thickness was controlled by the sensor resting on a long ski sliding on the paved surface. All material was placed to produce 1 1/2- or 2-in. compacted lifts as required.

The specifications required that the binder and the surface courses be compacted to 95 percent of maximum theoretical laboratory density. Usually, three passes with the three-wheel roller, seven to eight passes with a pneumatic-tired roller, and three passes with a tandem roller were required to achieve the required density. On the following day, core samples were taken from each course at 250-ft intervals. These specimens were used to check field density and air void measurements.

TABLE 30

RESULTS OF TESTS OF PLANT SAMPLES FOR BITUMINOUS SURFACE

	Surface Course Filler				Binder Course Filler	
	Asbestos Fiber	Hydrated Lime	Kaolin Clay	Limestone Dust	Asbestos Fiber	Limestone Dust
Stability, lbs	1310	1780	1640	1690	1620	1880
Flow, 0.01 in.	19.1	12.1	9.5	9.9	17.0	14.8
Sp. Gr. (d)	2.41	2.43	2.42	2.42	2.37	2.41
Sp. Gr. (D)	2.45	2.49	2.50	2.50	2.46	2.51
Filler, %	2.0	2.5	3.0	2.5	2.0	2.5
Asphalt, %	6.9	5.6	5.9	5.7	5.7	4.8

(d) bulk specific gravity
(D) theoretical specific gravity of voidless mixture

Routine samples taken from the surface course at locations within the experimental area showed the relative densities reported in Table 31.

Shoulders

Originally, both inside and outside shoulders were surfaced with crushed stone for their entire 10-ft width. However, the width of the shoulders in the westbound roadway had to be changed during rehabilitation to accommodate the 4- to 6-in. resurfacing while still maintaining a 4:1 sideslope. As can be seen in Figure 4, the inner shoulder was reduced from 10 to 8 ft, while the outer shoulder was extended to 12 ft by adding a soil wedge to the embankment.

The rehabilitated shoulders were surfaced with gravel which was the same material used as subbase. The gravel was placed 10 ft wide for outer shoulders and 4 ft wide for inner shoulders. Any remaining shoulder width was formed with an earth wedge (Figures 3 and 4).

In the case of resurfaced flexible test sections, the existing crushed stone surface was brought to grade with gravel. In all other cases, the thickness of gravel shoulder adjacent to flexible pavement was 9 3/4 in., regardless of base type. The lateral slope of embankment under shoulder was 1/4 in. per ft, but the lateral slope of the shoulder surface is 1/2 in. per ft.

TABLE 31

RESULTS OF CONSTRUCTION DENSITY TESTS FOR BITUMINOUS SURFACE

Section	Mineral Filler	Relative Density[1] (% of theoretical)
1	Asbestos fiber	98.4
3	Hydrated lime	97.6
4	Limestone dust	96.4
5	Kaolin clay	96.8

(1) Compacted density as percent of theoretical voidless density

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APPENDIX A

Layout of Test Sections

In Figure A-1 and A-2, the symbol identified as BC-Base Course is the crushed stone-special which was the original base material in the AASHO Test Road. Test sections 016 and 018, which have the same symbol, represent salvaged crushed stone-special placed when the pavement was rehabilitated.

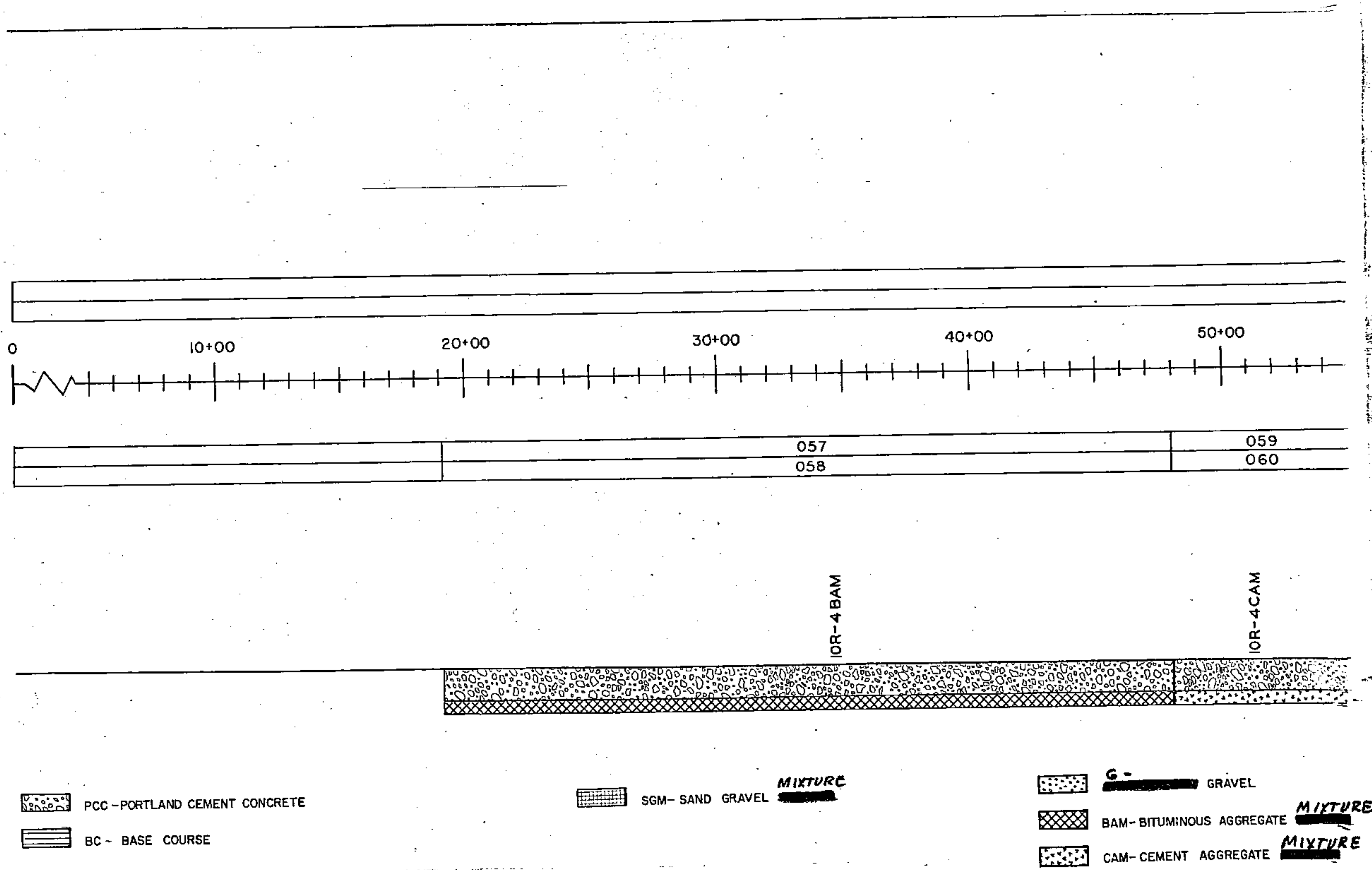

Figure A-1. Layout of test sections.

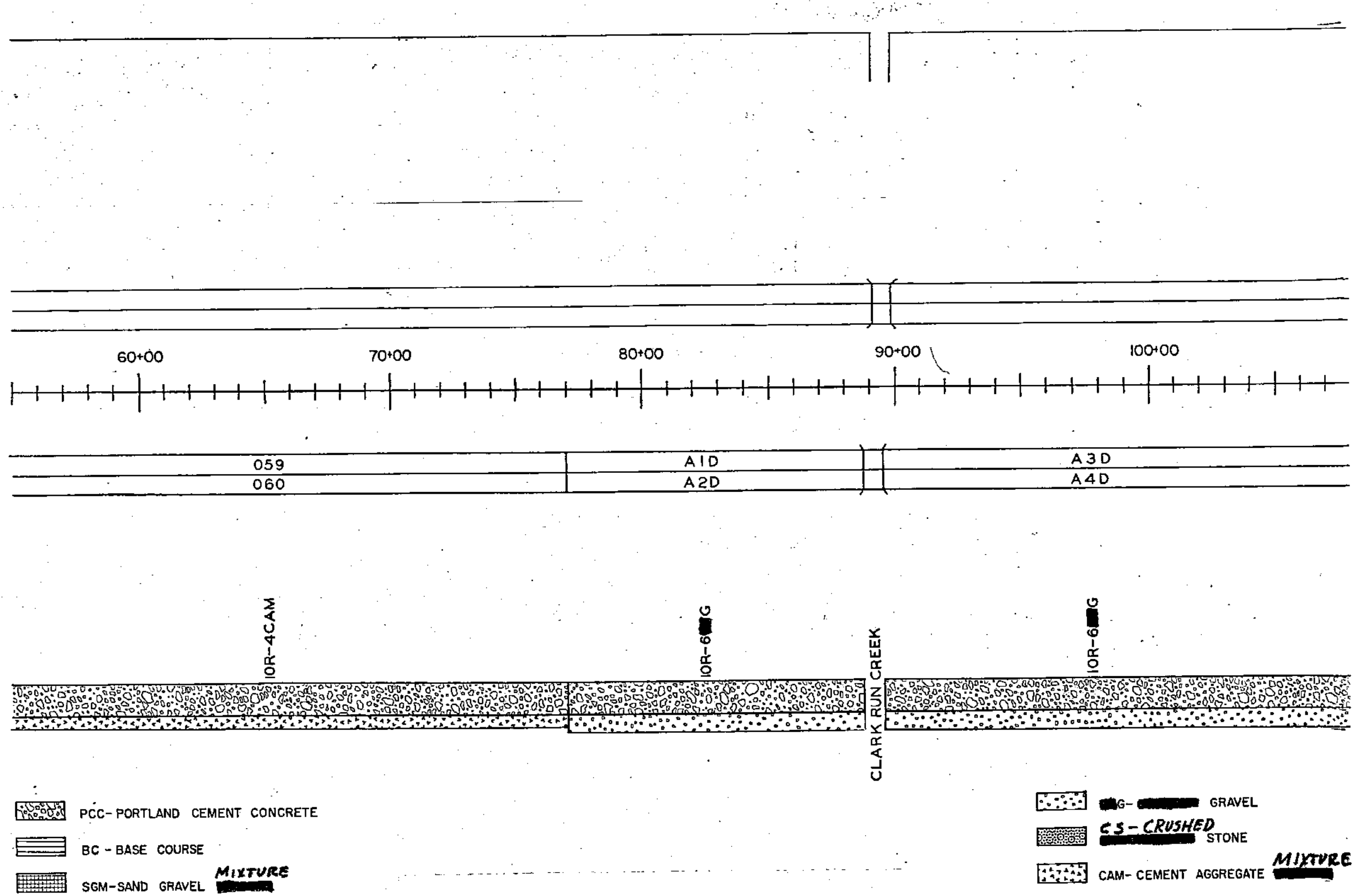

Figure A-1. Layout of test sections.
(continued)

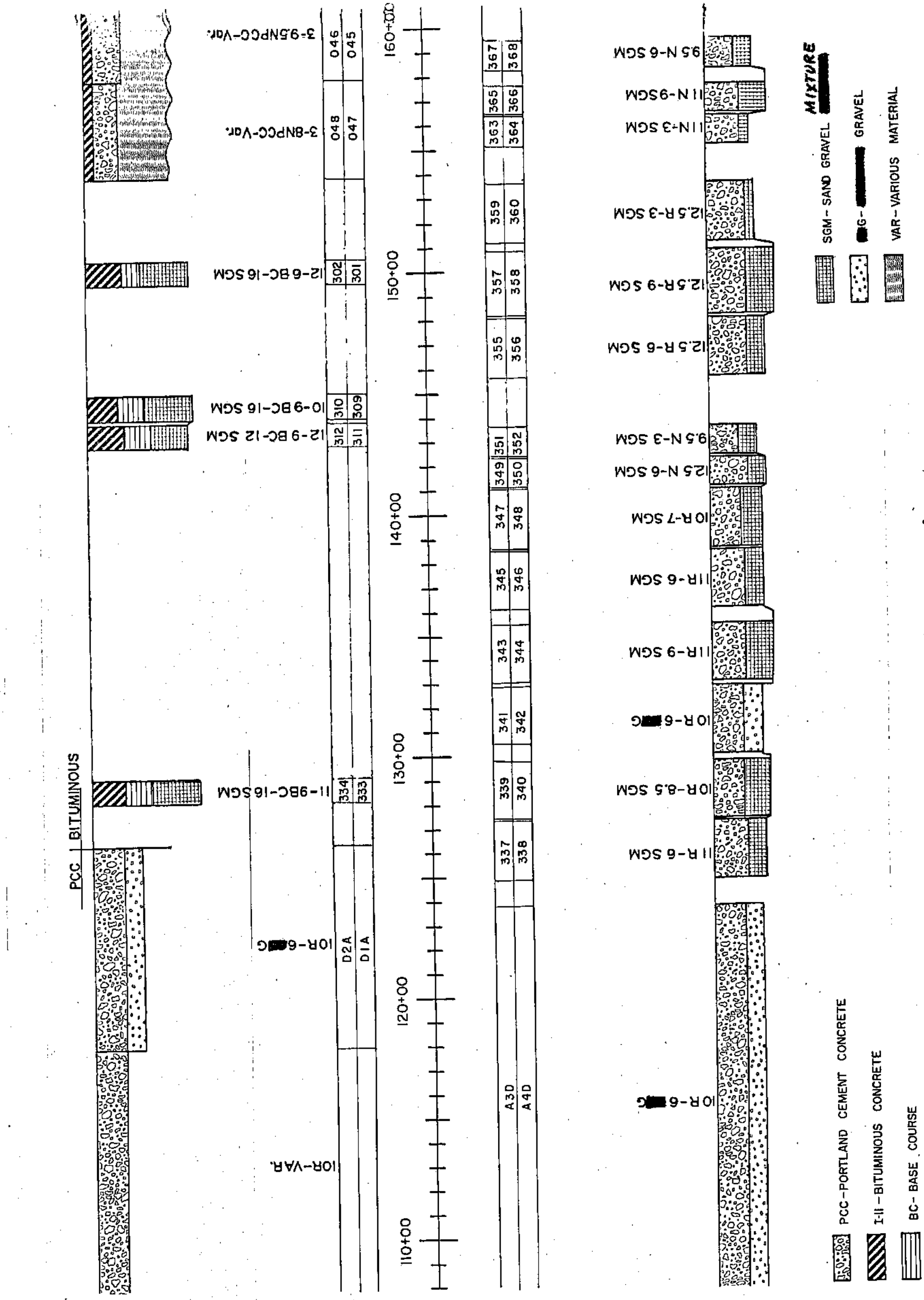

Figure A-1. Layout of test sections.
(continued)

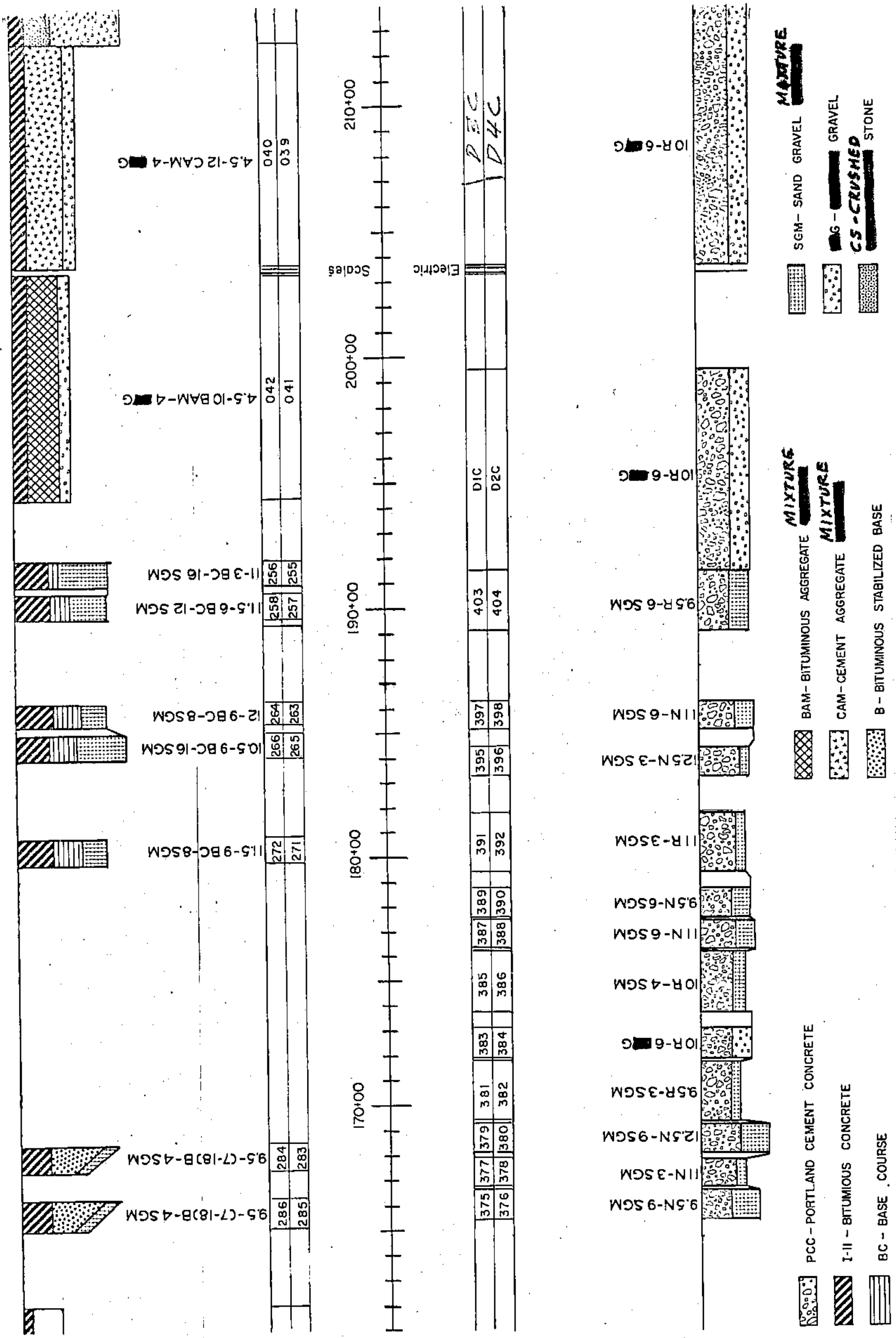

Figure A-1. Layout of test sections.
(continued)

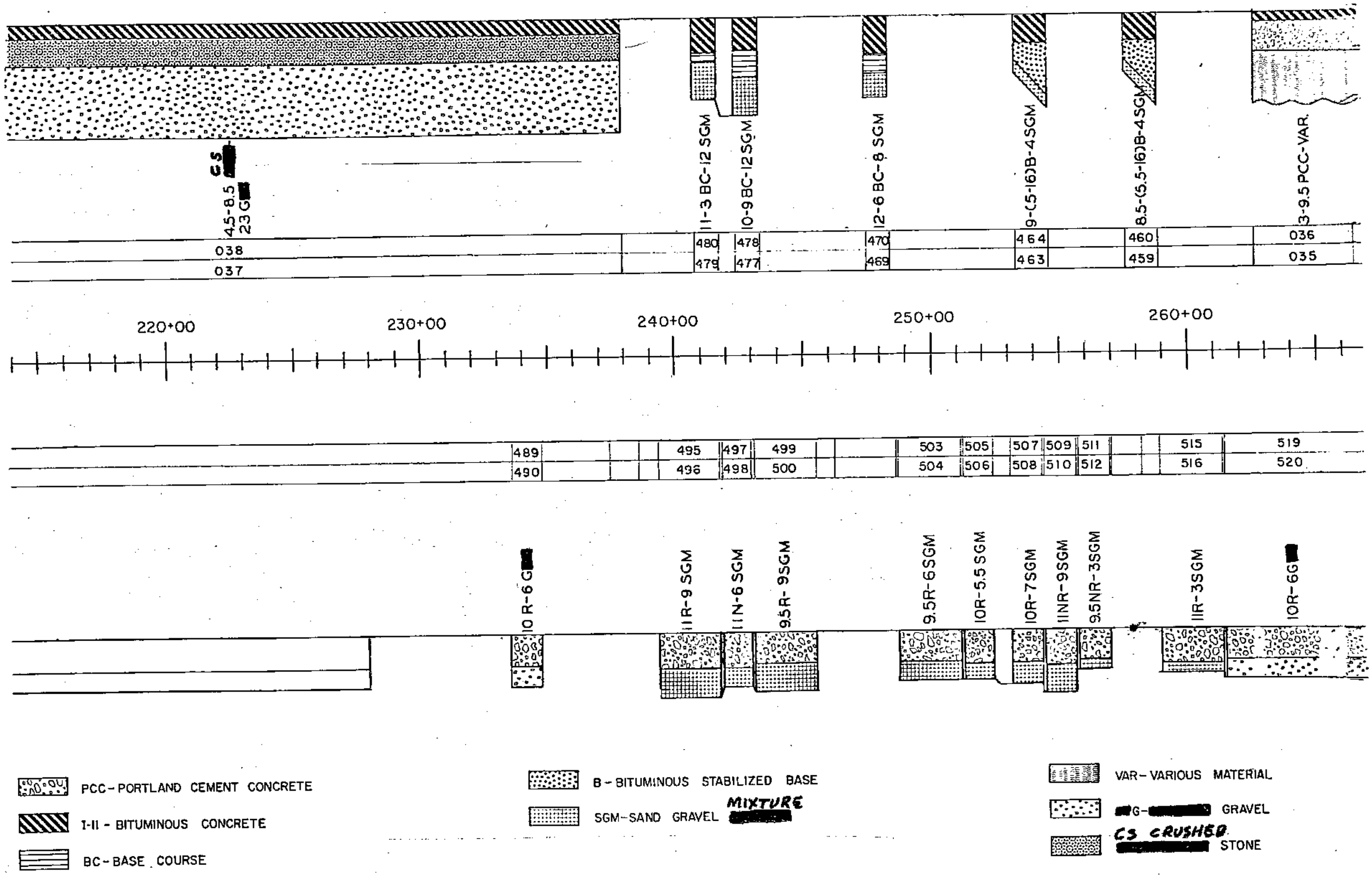

Figure A-1. Layout of test sections.
(continued)

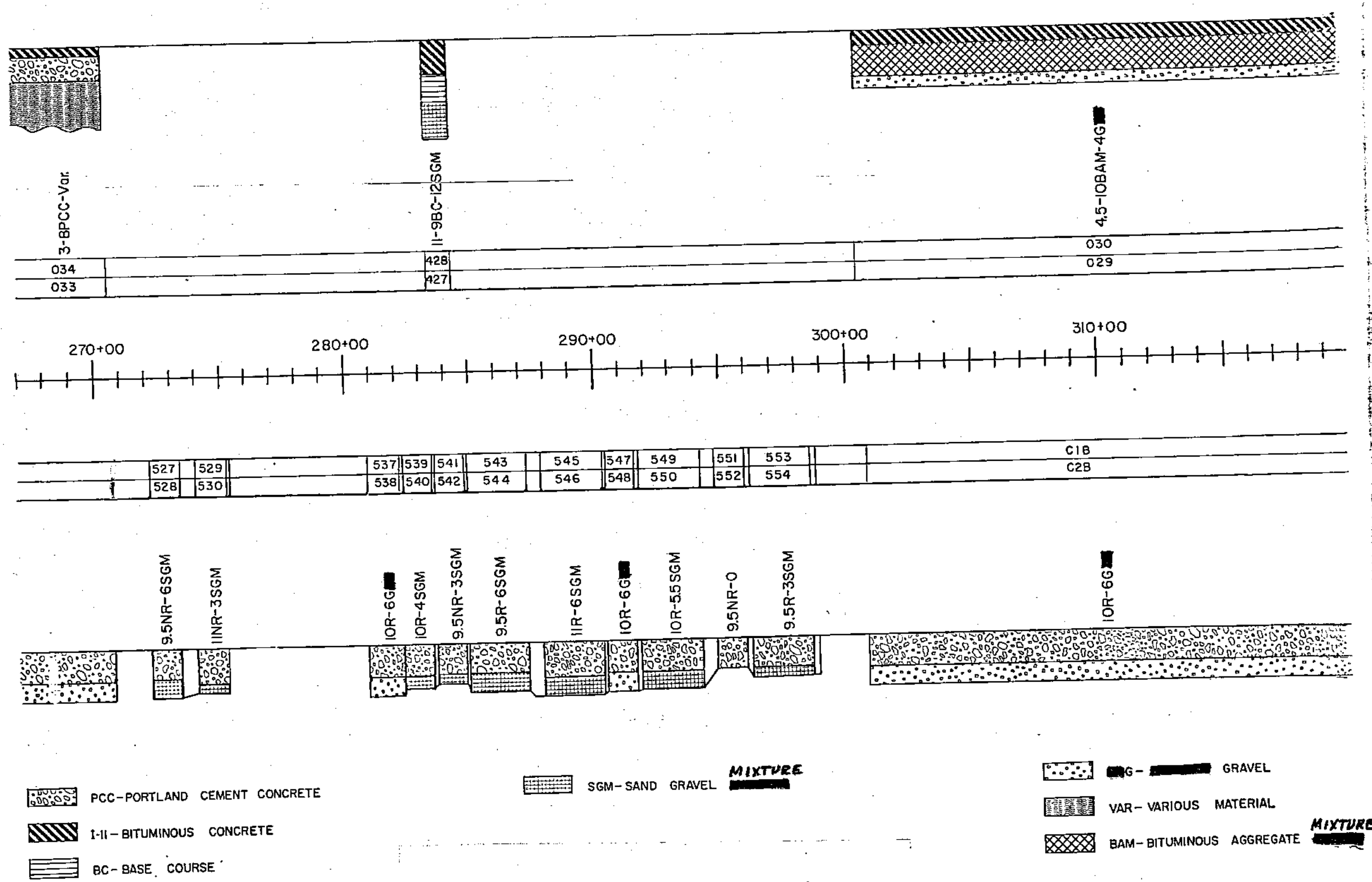

Figure A-1. Layout of test sections.
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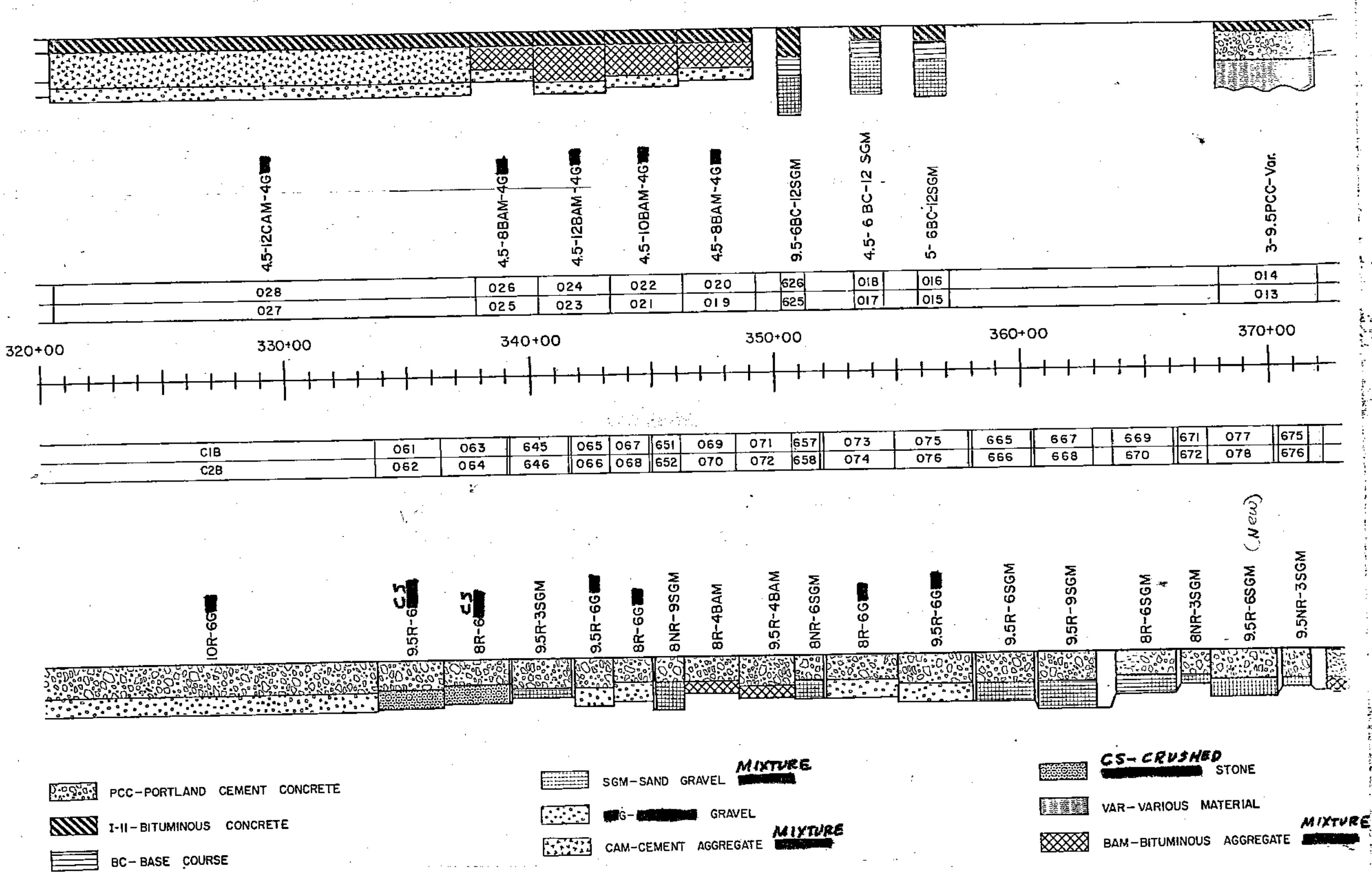

Figure A-1. Layout of test sections.
(continued)

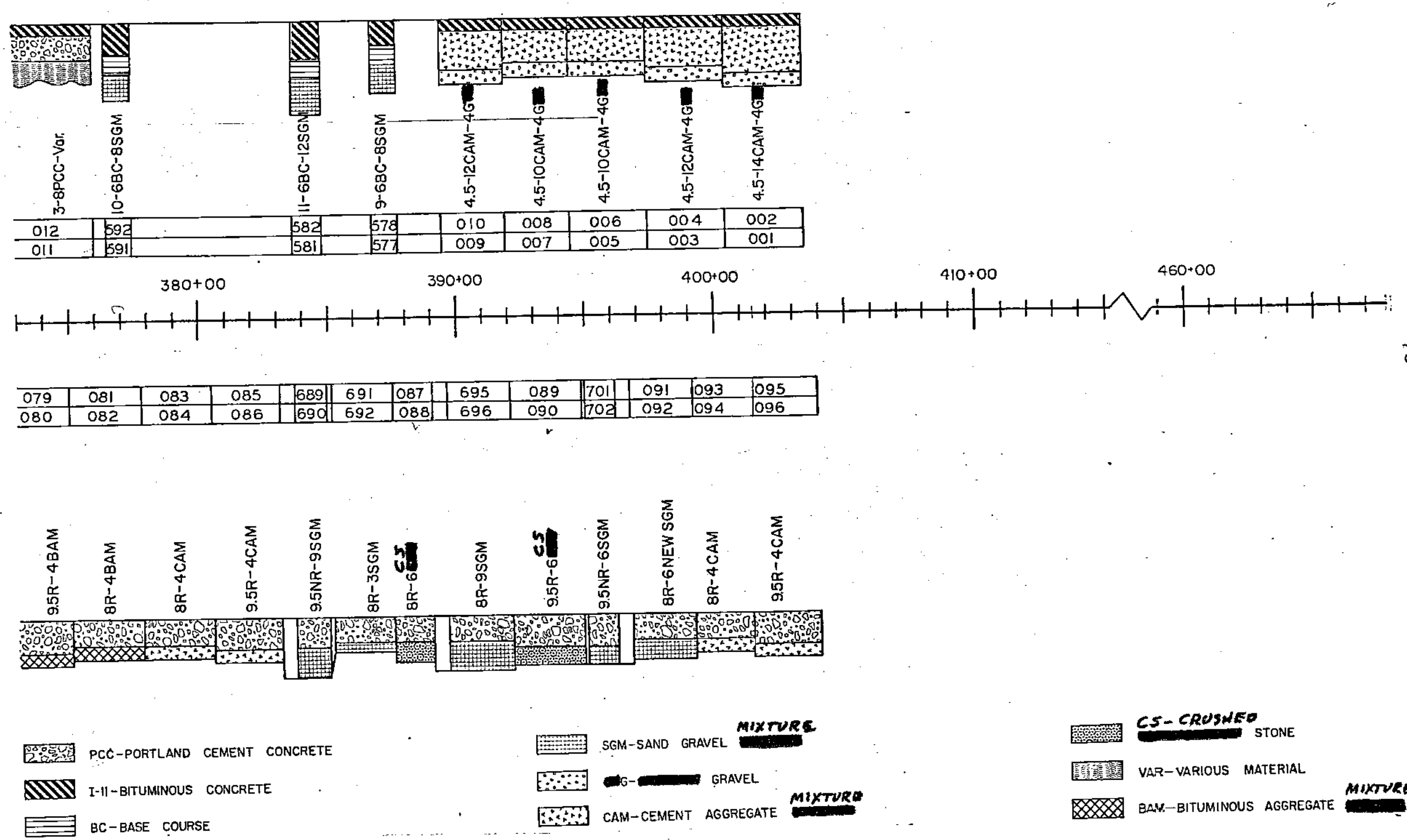

Figure A-1. Layout of test sections.
(continued)

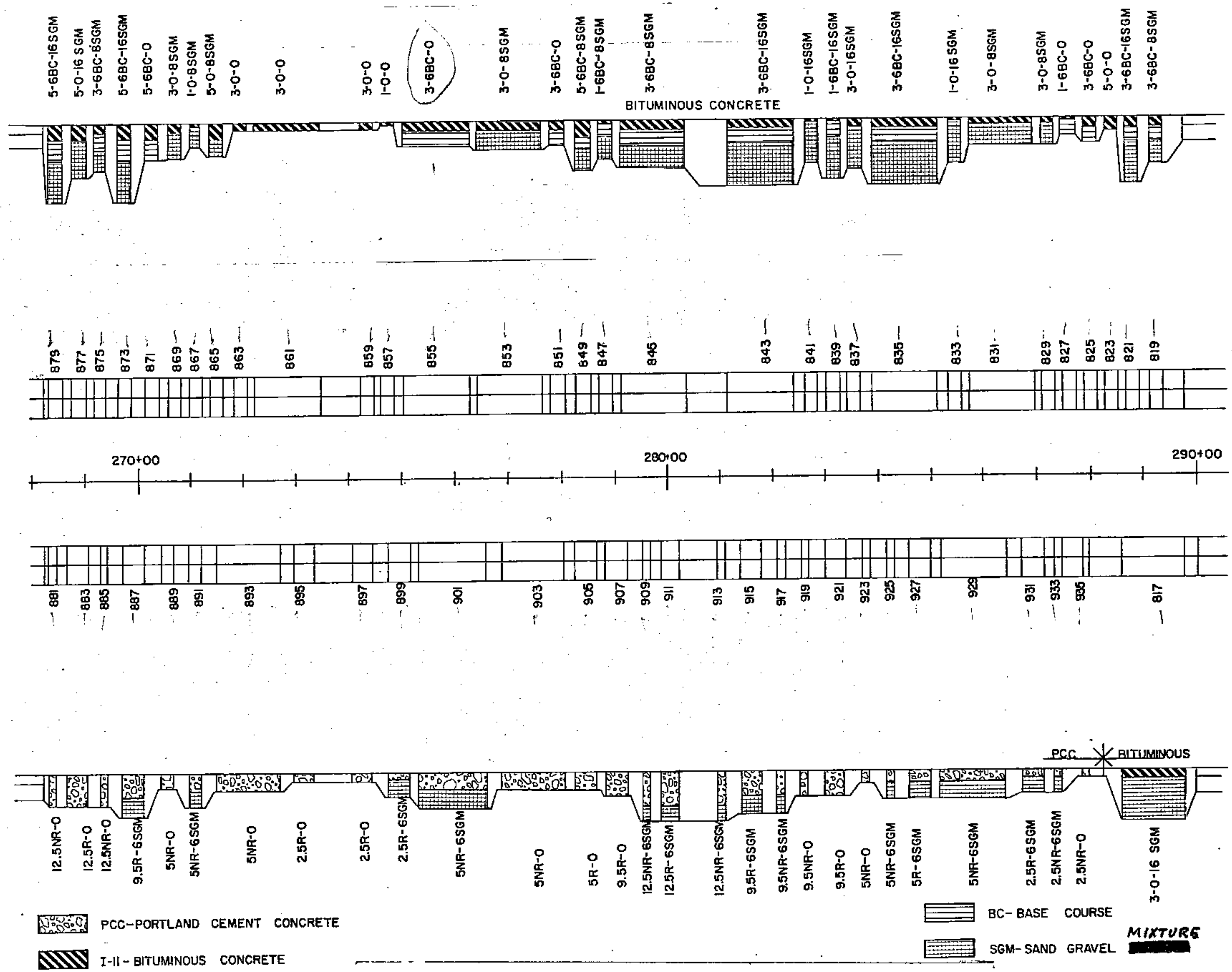

Figure A-2. Layout of test sections - Loop 1.